ELEMENTS OF STONE AND BRICK MASONRY

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Elements of Stone and Brick Masonry

By

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ELEMENTS OF STONE MASONRY
ELEMENTS OF BRICK MASONRY
AGREEMENTS AND SPECIFICATIONS

316

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ELEMENTS OF STONE MASONRY

Serial 1214 —— Edition 1

STONE CUTTING AND FINISHING

STONE-CUTTING TOOLS

1. Introduction.—Before treating of stone masonry, the preliminary work of dressing the stones for the wall should first be considered. While it is not necessary for a structural engineer to be an expert stone cutter, he should be familiar with the general principles of the art in order to be able to specify the proper treatment for a certain class of work and to know when it is well done.

2. Hammers.—In Fig. 1 are shown the various hammers used for cutting and dressing stone.

The **double-faced hammer**, shown at (*a*), weighs from 20 to 30 pounds, and is used for breaking and roughly shaping the stones as they come from the quarry.

The **face hammer**, shown at (*b*), is a lighter tool than the double-faced hammer, but it is used for the same purposes when less weight is required. It has one blunt and one cutting end, the latter being used for roughly dressing the stones preparatory to using the finer tools.

The **pick**, shown at (*c*), is used for coarsely dressing the softer stones. Its length is from 15 to 24 inches, and the width at the eye is about 2 inches.

The **ax**, or **peen hammer**, shown at (*d*), is about 10 inches long, and has two cutting edges about 4 inches in length. It is used principally for making *drafts*, or margin

lines, around the edges of stones, and also for dressing the faces, being used after the point and before the patent hammer.

The **tooth ax,** shown at (*e*), has its cutting edges *a* notched to form teeth, the number of these teeth varying

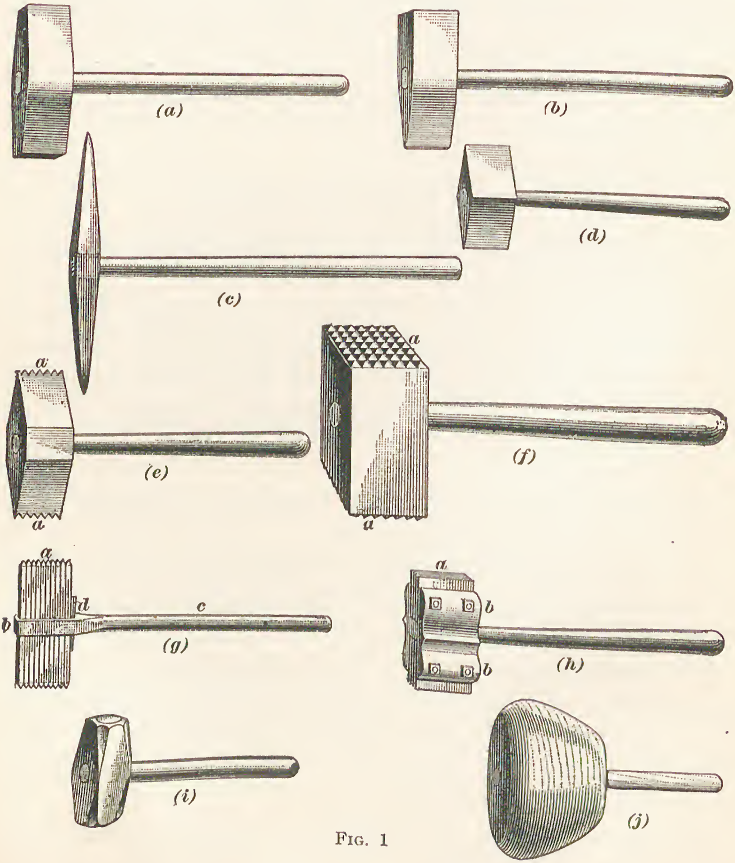


FIG. 1

according to the fineness of the work. It is used for roughing soft stones to an approximately flat surface before the finishing tool is used; but it is not used on hard stones, like granite and marble, as the points would become dull quickly and need constant sharpening.

The **bush hammer,** shown at (*f*), is from 4 to 8 inches long, with ends from 2 to 4 inches on a side. These ends are cut into a number of pyramidal points, as shown at *a*. This kind of hammer is used for finishing limestones and sandstones after the surfaces have been made nearly even.

The **crandall,** shown at (*g*), consists of ten or twelve steel bars *a* and a malleable-iron handle *c*. In the end of the handle is a slot *b*, in which the bars are firmly held in place by a key *d*. The bars are made of $\frac{1}{4}$-inch steel, are about 10 inches long, and are pointed at each end, as shown. The crandall is used to complete the finish of sandstone after the surface has been partly worked with a tooth ax or a chisel.

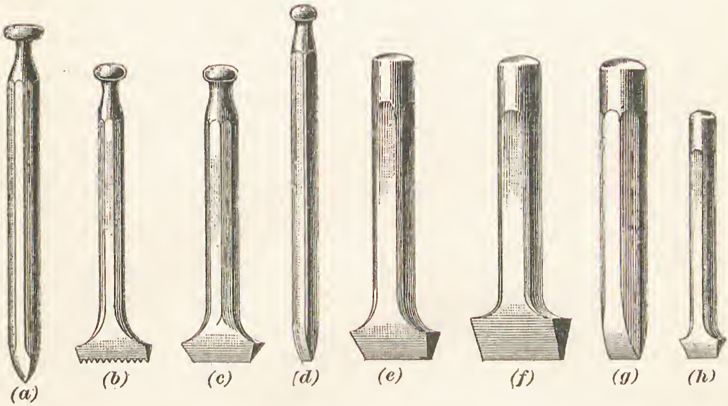


Fig. 2

The **patent hammer,** shown at (*h*), is made of from four to ten thin steel blades. These blades are ground to an edge and are held together by means of bolts, as shown at *b*. This hammer is used to finish granite or hard limestone. The number of blades required to give the proper fineness to the cutting is usually specified as four, six, eight, or ten cut.

The **hand hammer,** shown at (*i*), is used in drilling holes and in pointing and chiseling the harder rocks. It is about 5 inches in length and weighs from 2 to 5 pounds.

The **mallet,** shown at (*j*), is used in cutting the softer stones. It is made of wood, the head being about 7 or 8 inches in diameter and 5 or 6 inches in height.

3. Chisels.—In Fig. 2 are shown the different chisels used for dressing stone.

The **point,** shown at (*a*), is made of round or octagonal steel, 8 to 12 inches long, with one end pointed. It is used for chipping off the rough faces of the stone and reducing them to approximately plane surfaces, ready for the peen hammer, and also to give a rough finish to stone in *broached* and *picked work.*

The **tooth chisel,** shown at (*b*), is used only on soft stones, serving much the same purpose as the tooth ax.

The **drove chisel,** shown at (*c*), is 2 or 3 inches wide at the end. It is used for cutting or driving the rough surfaces of the stone.

The **pitching chisel,** shown at (*f*), is used for making pitched-face work.

Other forms of chisels used for dressing soft stone are shown at (*d*), (*e*), (*g*), and (*h*).

4. Machine Tools. — Besides the hand tools just described, there are many machine tools employed to prepare the stone for the finer treatment to be given by hand work. The machine tools include *saws*, *planers*, *grinders*, and *polishers*.

The **saws** used for cutting stone are merely thin sheets of steel, the edges of which are not sharp. There are three styles of stone-cutting saws, namely, the *drag*, the *circular*, and the *band saw.* The **drag saw,** which is similar in shape to the ordinary cross-cut saw, has a forward-and-backward movement The **circular saw,** as the name implies, is a circular disk that revolves on an axis through its center. The **band saw** is a continuous steel band, or belt, that runs on two driving wheels. These saws are aided in cutting by feeding sand and water in the groove that is being made in the stone.

The **planer** is a machine used in reducing the inequalities in rough stone. It consists of a table that moves horizontally under a cutter, the stone to be trimmed being fastened on the table by means of clamps.

The **grinder** and the **polisher** are practically alike so far as construction is concerned. They differ only in the fineness of surface they are capable of producing. The machine used for grinding or for polishing consists principally of a circular horizontal table on which the stone is fastened, the face to be polished being always turned upwards. This table, with the stone, revolves about a vertical axis through its center, and a horizontal metal plate that can be moved up and down, but will not revolve, is pressed on the stone. Sand and water are supplied between the plate and the stone, whose surface is thus abraded until the proper degree of smoothness is attained.

FINISH OF STONEWORK

5. Stereotomy.—The science of making patterns, or templets, to which a stone is to be cut to fill a certain place in an arch or other complicated piece of stonework, is called **stereotomy.** In practice, the engineer makes a drawing of the intended stonework, showing where the joints in the face are to be located, and the stone cutter then details each block and cuts it to fit exactly with the others. It is therefore important for the engineer to understand the different finishes to which stone is dressed, but it is not necessary for him to be able to make the templets for each stone.

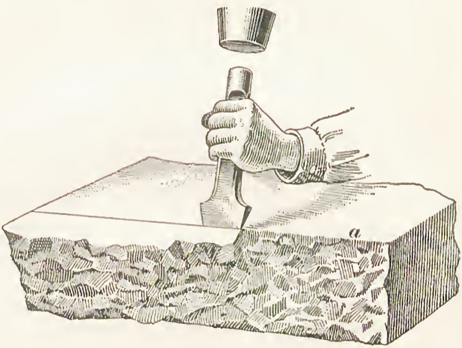


Fig. 3

6. Rock-Faced Work.—In Fig. 3 is shown **rock-faced,** or **pitch-faced, work,** and the method of using the pitching chisel. The face of the stone is left rough, just as it comes from the quarry, and the joints, or edges, are *pitched* off to a line, as shown at *a*. As this finish requires very little

work, rock-faced dressing is cheaper than any other kind, especially when granite or hard limestone is used.

7. Margins.—Building stones are often faced an inch or so from their edges. This dressed strip, shown at *a*, Fig. 4, is known as the **margin,** or **draft line,** to distinguish it from the rock-faced work at *b*. This margin is cut on soft stone with a chisel, but on extra-hard stone, such as granite, it is usually cut with an ax, or peen hammer.

8. Pointed Work.—In producing **pointed work,** a pointed chisel is run over the face of a stone to knock off any large projections. This work is called *rough-* or *fine-pointed work*, according to the number of times the work is gone over. In Fig. 5 is shown an example of rough-pointed work, while in Fig. 6 is shown an example of fine-pointed work that is also margined.

9. Tooth-Chisel Work.—The finish called **tooth-chisel work** is produced by dressing stone with a tooth chisel. The surface of a stone finished in this way resembles pointed work, but it is not so regular. Working stone with a tooth chisel is one of the cheapest methods of stone dressing known.

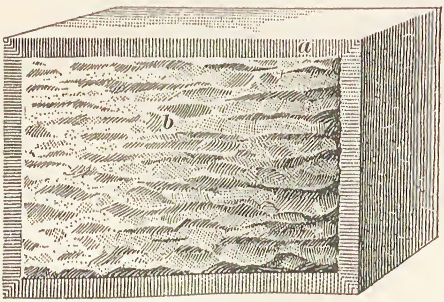


Fig. 4

10. Broached Work.—Fig. 7 illustrates what is known as **broached work.** In this kind of work the stone is dressed with a point so as to leave continuous grooves over the surface. At *a* is shown the margin, or draft line, and at *b*, the broached center, which is cut in two directions in order to illustrate *right-* and *left-hand broaching*.

11. Tooled Work.—For **tooled finish** a tooth chisel from 3 to 4½ inches wide is used. In this kind of work,

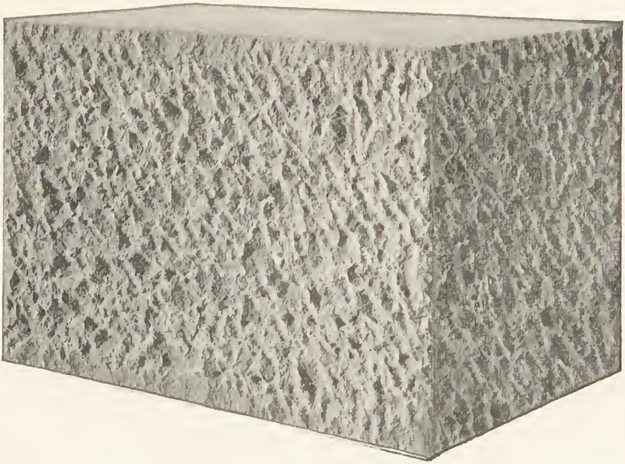


Fig. 5

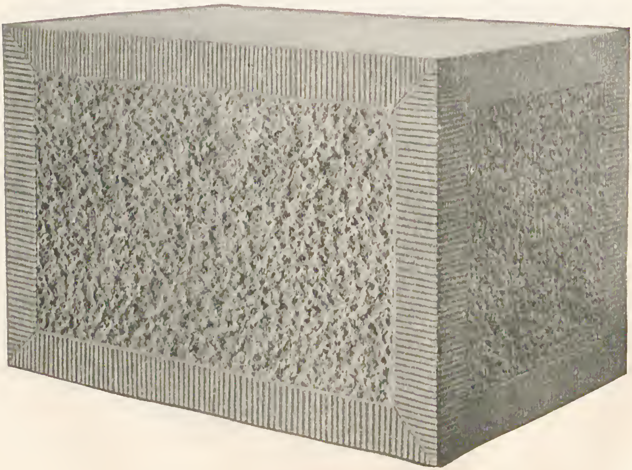


Fig. 6

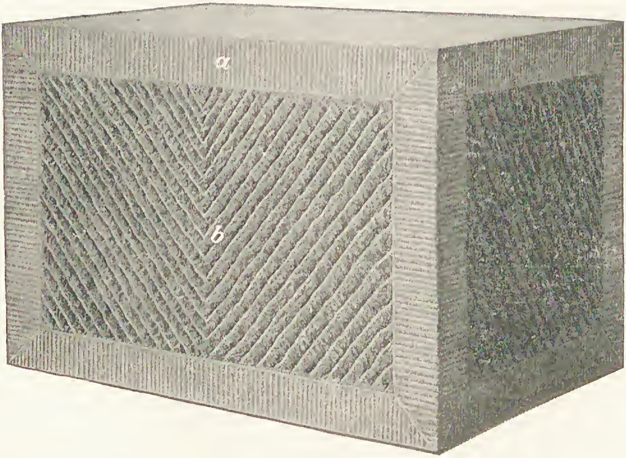


FIG. 7

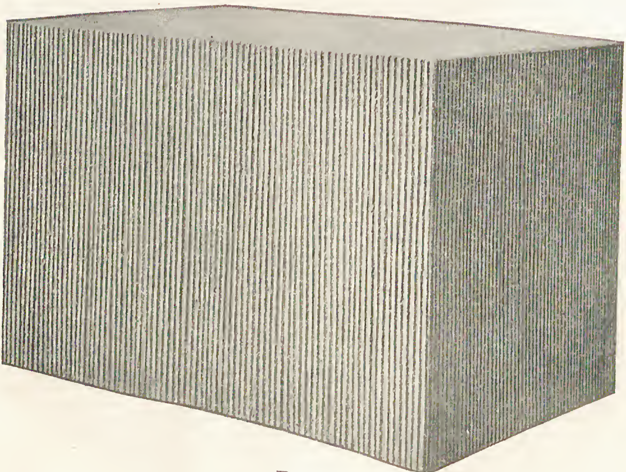


FIG. 8

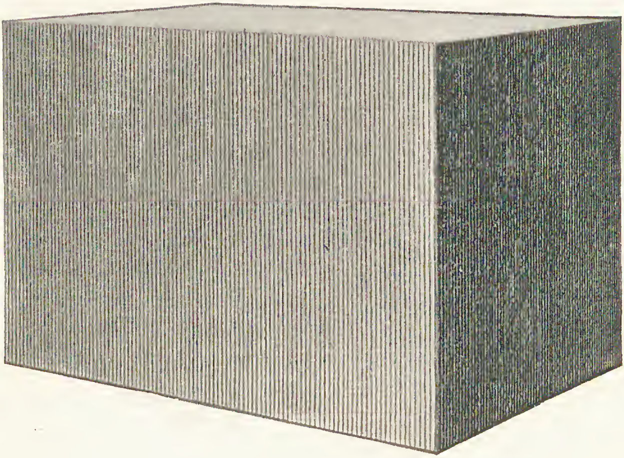


Fig. 9

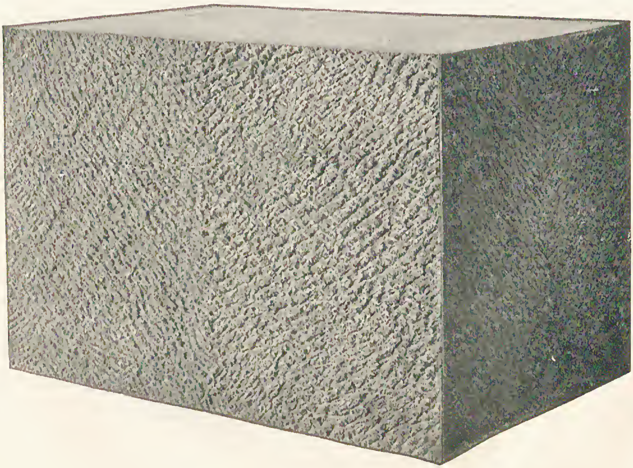


Fig. 10

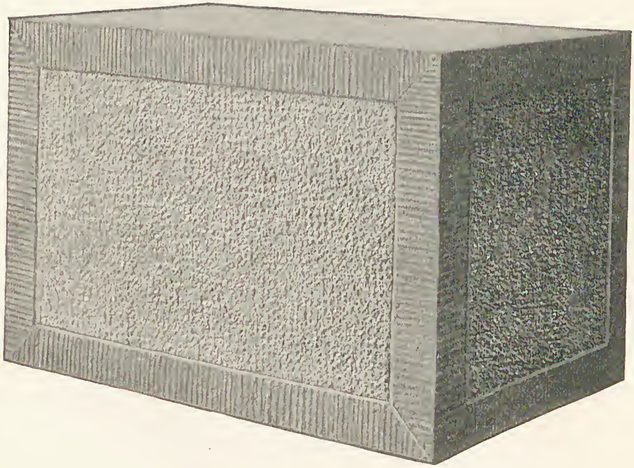


Fig. 11

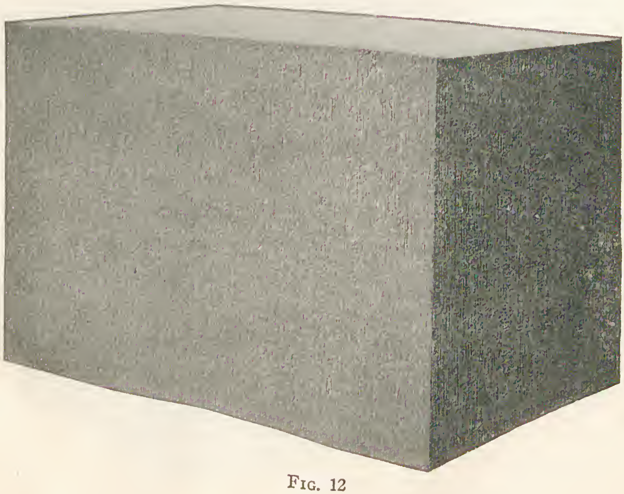


Fig. 12

the lines are continued across the width of the stone to the draft line (when one is used). When well done, tooled work makes a very good finish for soft stones.

12. Drove Work.—The finish known as **drove work** is somewhat similar to tooled work, but it is generally executed on harder stone. There are two general classes of drove work, namely, *hand drove* and *machine drove*, the former being shown in Fig. 8 and the latter in Fig. 9. Machine-drove work, as will be noticed, is more regular than hand drove; also, the cuts are a little deeper, although this is hardly apparent from the illustration. For a large quantity of cutting, machine work is cheaper than hand work; it is not so pleasing in appearance, however.

13. Crandalled Work.—In Fig. 10 is shown **crandalled work,** which, when well done, gives the stone a fine, pebbly appearance. This finish is especially effective for the red Potsdam and Longmeadow sandstones. In the Eastern States, it is used for sandstones probably more than any other finish.

14. Rubbed Work.—In producing the finish known as **rubbed work,** the surfaces of stones are rubbed with a piece of softer stone, together with sand and water, until perfectly smooth. Sandstones and most of the limestones are finished in this manner, and if granite, limestone, and marble are rubbed long enough, they will take a beautiful polish. The operation of rubbing can be performed either by hand or by machine.

If the rubbing is done soon after the stones are sawed into slabs and are still soft, it is cheaply and easily performed, as the sawing makes the face of the stone comparatively smooth.

15. Bush-Hammered Work.—In Fig. 11 is shown the finish of a stone after having been **bush-hammered.** This finish, which leaves the surface of the stone full of points, is a very attractive one for hard limestones and sandstones, but should not be used in dressing the softer kinds.

Fig. 13

16. Patent-Hammered Work.—A stone finished by a **patent hammer**, which is generally used on granite and hard limestone, is shown in Fig. 12. The stone is first dressed to a fairly smooth surface with the point and then finished with the patent hammer. The degree of fineness in the finish is determined by the number of blades in the hammer, the usual number being eight or ten. The ax may be used instead of the hammer, but more time is required to obtain an equally good finish.

17. Vermiculated Work.—In Fig. 13 is shown a stone having a somewhat elaborate finish, which is known as **vermiculated** from the worm-eaten appearance. Stones cut in this manner are used principally as quoins, or corner stones, and in base courses. Owing to the cost, this style of dressing is not often used in the United States.

A simple method of obtaining the vermiculated effect is by the use of a patented *sand-blast process*. The sand employed in this process is carborundum dust, which is one of the hardest substances known. It is blown against the stone with high velocity by means of compressed air. While this sand will rapidly cut and wear away hard surfaces, such as stone, it will not cut soft, yielding surfaces, because the latter do not suddenly stop its motion, but, by giving way slightly, permit it to sink in a short distance and then rebound. For this reason, the nozzle of the blowing machine is made of soft rubber and those portions of the stone that it is desired to have raised are covered with beeswax, asphalt, or even heavy paper. The remainder of the face of the stone is eaten away by the sand blast. When the proper depth has been reached, the sand blast is stopped and the material used to cover the raised part of the stone is removed. It is then necessary to put on a few finishing touches with a pointed chisel, when the stone is ready to go in the structure.

The sand blast is also used to clean stonework that has become soiled and stained by smoke and dust.

18. Scale Work.—A pleasing and novel method of stone dressing, presenting a striking effect of light and shade,

is illustrated in Fig. 14. The finish shown at (*a*), known as **scale work,** is obtained by cutting out rows of shallow flutes between the drafts of the stone with about a 1-inch

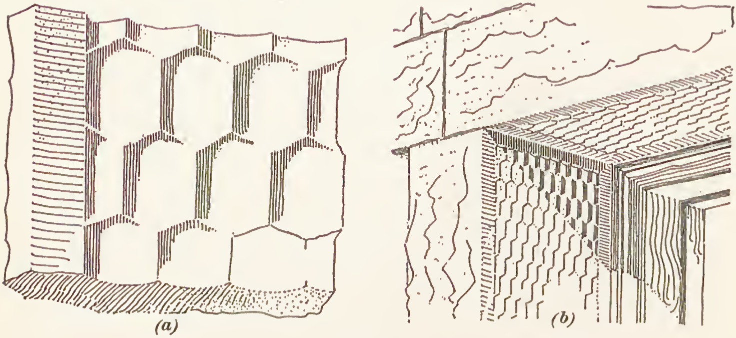


FIG. 14

tool. The flutes are about 1 inch wide, and are alternated so that each successive course "breaks into" the preceding one and forms with it a series of hexagonal hollows, giving a honeycombed appearance. The application of this finish to a window jamb is shown at (*b*). This unique method is

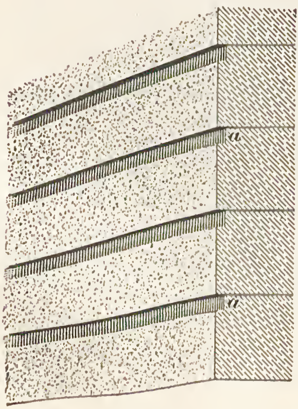


FIG. 15

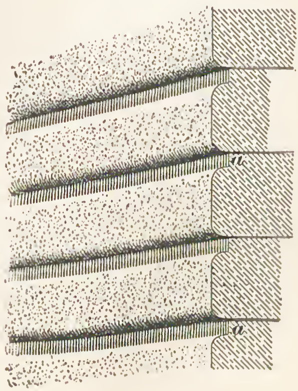


FIG. 16

applicable, of course, only to soft stones, such as limestone, but to these it gives a beautifully crisp and varied surface The cutting can be done either by hand or by machinery.

19. Rusticated Work.—The term **rusticated work** is generally used to designate sunken or beveled joints. Two examples of this finish are illustrated in Figs. 15 and 16, the former showing the stones with recesses *a* having sharp edges and the latter with recesses *a* having rounded edges. This style of work is expensive, and is usually employed in the finish of basement work or to emphasize piers and other projections.

STONE MASONRY

GENERAL CONSIDERATIONS

20. The stonework entering into the construction of buildings may be divided into three classes: *rubble*, *ashlar*, and *trimmings*. Before describing these, however, a few general observations, applying to all classes of stone masonry, are necessary.

Whatever may be the quality of mortar used, the wall should contain as much stone and as little mortar as possible, as the former is the stronger material. In rough walling, if the stones are pressed together until the more prominent angles on their faces come almost into contact, the interstices being filled with mortar, there results better work than if a thick, yielding mass of mortar is allowed to remain in the joints. Absolute contact, however, is not advisable, as the mortar in drying shrinks and may leave the stones bearing only on the projecting angles.

The joints in stonework vary in thickness from $\frac{3}{16}$ to $\frac{1}{2}$ inch. A $\frac{1}{4}$-inch joint is probably the best for ordinary work, while a $\frac{1}{2}$-inch joint should be used for rock-faced work only.

21. Stone being of a brittle nature, the longer pieces in a wall must be properly supported and well bedded in order to prevent them from breaking. It is also best to avoid extremely long stones, although the length of a stone should be greater than its height, especially in ashlar work, on

account of the vertical bond. There is a certain medium that should be observed; and while a compact mass, broken as little as possible, is most desirable in stone as well as in brick walls, the mason will often find it better to break a very long stone into two or more shorter ones, even though by so doing additional joints are made. However, in laying very long stones, as in steps or copings, it is customary to bed them only at the ends, so that when the mortar joint shrinks there will be no danger of the stones being broken by bearing on some obstruction at their middle.

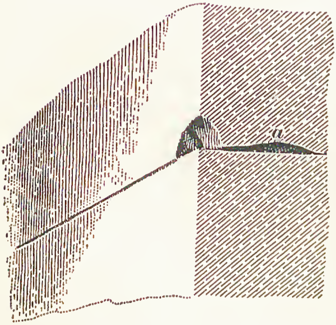


Fig. 17

The best stones should be used for piers, jambs, sills, lintels, cornices, band courses, etc. in the order mentioned; and all stones in which the length of the face is greater than its height should be so quarried that they can be laid on their natural beds, except, of course, piers and long jambs, which necessarily have the bed of the rock vertical.

22. Defective Methods.—A stone with a hollow cut in it, as shown at *a*, Fig. 17, should never be used in a wall, because when the mortar shrinks, the stone will bear only at the edges and is liable to spall, or chip off, with the result shown in the illustration. If not closely watched, careless stone masons are tempted to cut stones in this manner, as it is much easier than cutting them to a true bed.

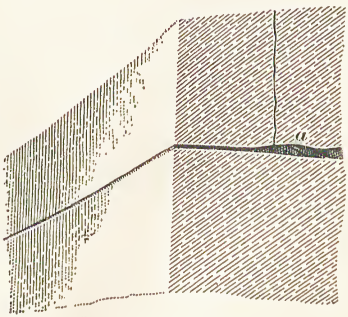


Fig. 18

Another improper method often carried out by masons is to cut the stone as shown in Fig. 18 and underpin the back with spalls. This practice is

also liable to lead to disaster, as the stone may split as shown at *a*.

On account of the liability of spalling, as illustrated in Fig. 17, rusticated joints are often used in the basement and first story of tall buildings.

RUBBLEWORK

23. Rubblework consists of stones in which the adjoining sides are not required to be at right angles. It is used for rough masonry, as in foundations, backing, etc., and frequently consists of common field stone, roughly dressed; but whenever possible, quarried rubble should be used, as better bedding can thus be secured. Conglomerate and slate stones

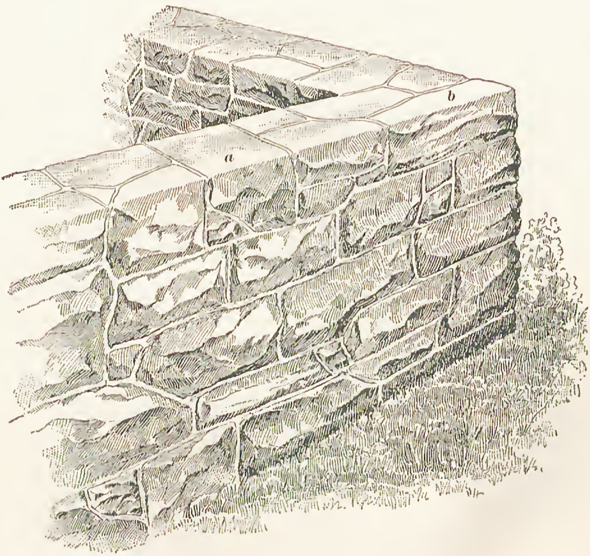


FIG. 19

abound in many localities, and are cheap and durable, but they do not cut easily. Such stones are often used with good effect, however, in walls with cut-stone or brick trimmings; or, when good lengths can be had, they are used for rock-faced sills, lintels, and trimmings.

24. Rubble Walls.—Fig. 19 illustrates a good **rubble wall,** the stones being bonded about every 4 or 5 feet, as shown at *a*. The largest and best stones should be placed at

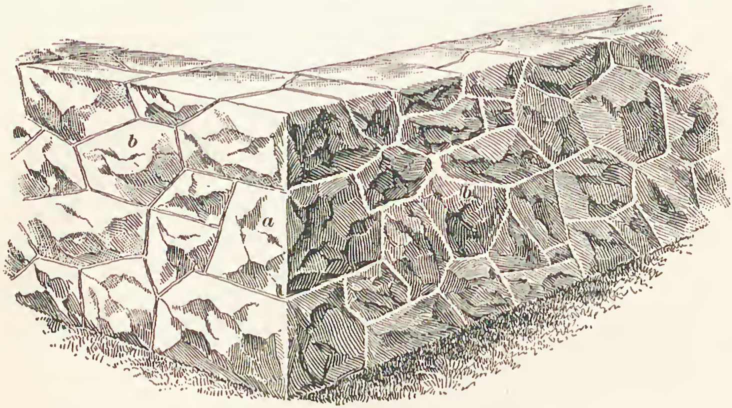


FIG. 20

the bottom and at the angles, as indicated at *b*, and should be laid up in alternate courses of headers and stretchers. Such work is generally laid with beds and joints dressed but very

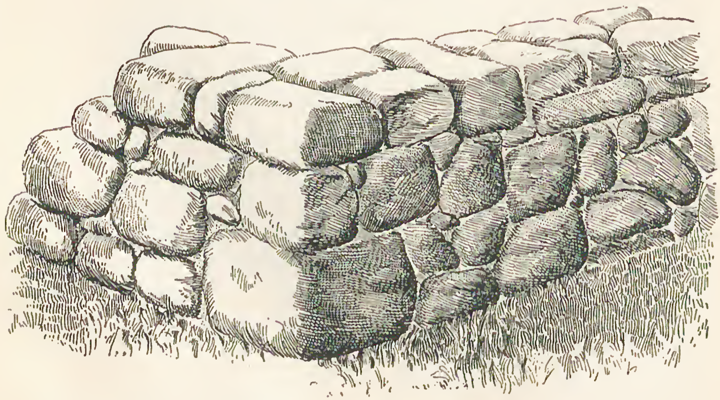


FIG. 21

little, the rough angles only being knocked off. The stones are set irregularly in the wall and the interstices are filled with spalls and mortar. If better work is desired, the joints

and beds of the stonework should be hammer-dressed. Such walls are frequently pointed with colored mortar, showing raised joints.

25. Fig. 20 shows a form of rubble masonry much used for country and suburban work. The quoins, or corner stones, *a* are hammer-dressed on top and bottom, and may be either cut stone or rock face. The latter finish harmonizes well when stones similarly dressed are in the body of the wall.

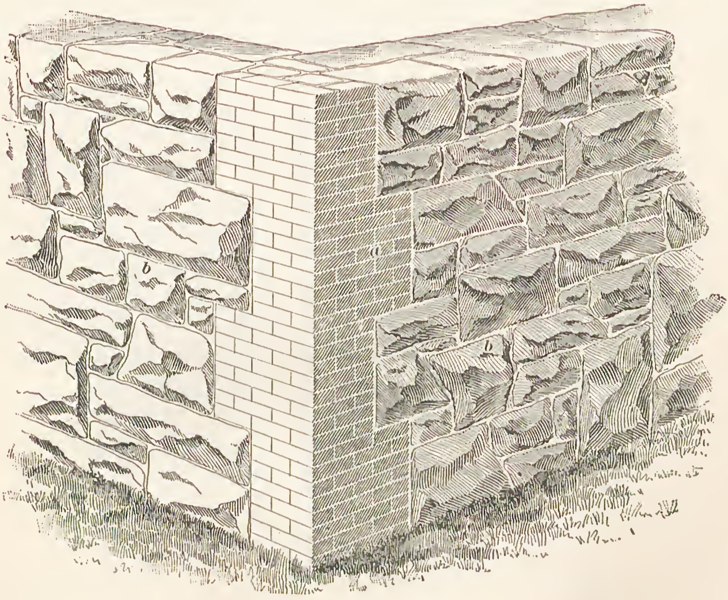


Fig. 22

All joints should be hammer-dressed, as shown at *b*, and no spalls should show on the face, while the mortar joints should not exceed ½ to ¾ inch in thickness. This makes an effective wall, especially for country churches, lodges, and other small buildings; but the work is expensive, owing to the labor required in dressing the joints.

26. Field-Stone Walls.—In Fig. 21 is shown a **field-stone wall.** Walls of this kind are built of small, uncut

boulders, and are frequently employed for fences and rustic-house work. Such walls should be made quite thick on account of the round and unstable shape of the stones used in their construction.

27. Walls With Brick Quoins.—Fig. 22 shows a rubble wall with **brick quoins,** or corners, at *a*. In this case, all the top and bottom joints of the rubblework have *level beds*, as at *b*. This kind of construction makes a very effective wall, and can be built quite cheaply when the stone used splits readily, or can be laid on its natural bed, thus requiring but little dressing.

28. Coursed Rubble.—In walls of **coursed rubble**, some effort is made to produce a coursed effect. Stone of ran-

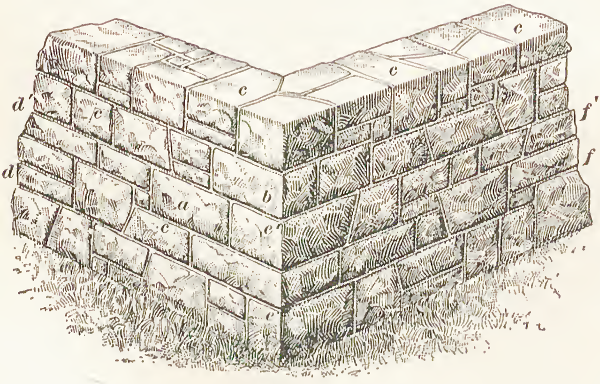


Fig. 23

dom sizes is used, but little or no attention is paid to uniformity of height in the different courses. For such walls, the stones are generally roughly dressed before the wall is begun. Care should be taken to get as nearly parallel beds as possible, and to bring the face of each stone to a fairly even surface at approximately right angles to the beds. The quoins in coursed rubble are usually dressed and laid with more care than the remainder of the work; they also serve as gauge

courses. Coursed rubble, when well built, makes a very solid wall and is extensively used.

Fig. 23 illustrates a coursed rubble wall, the rubblework being shown at *a*; the quoins, at *b*; the bond stones running through the walls, at *c*; and two of the course joints, at *d e f* and *d′ e′ f′*.

ASHLAR

29. Stonework that is cut on four sides so that the adjoining sides will be at right angles to each other, is known as **ashlar,** no matter whether the face is dressed or not.

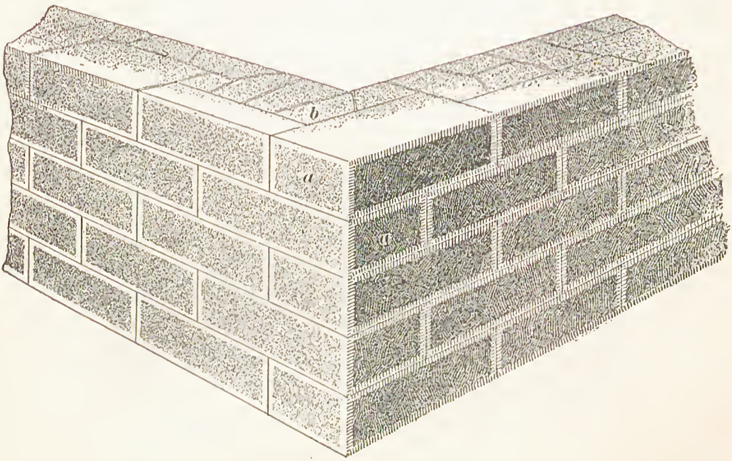


Fig. 24

From Fig. 23 it is evident that some stones of this form are also found in coursed rubble. The latter may therefore be considered as the connecting link between rubble and ashlar stonework.

In the following description it should be understood that the style of ashlar designated has nothing to do with the finish on the face of the stone, but simply the manner in which it is laid, although certain kinds of ashlar are generally made with the styles of dressing shown in the illustrations.

Ashlar is usually laid either in regular courses with continuous horizontal joints, as shown in Figs. 24, 25, and 26, or in

broken courses, without regard to continuity of the joints, as shown in Figs. 28 and 29. All ashlar should have straight and horizontal bed joints, and the vertical joints should be kept plumb. If the work is not done in this manner, ashlar walls will present a poor appearance.

30. Coursed Ashlar.—A class of stonework in which the blocks are uniform in size and the bed joints are continuous is known as **coursed ashlar.** When such stones can be obtained readily, this kind of work is not very

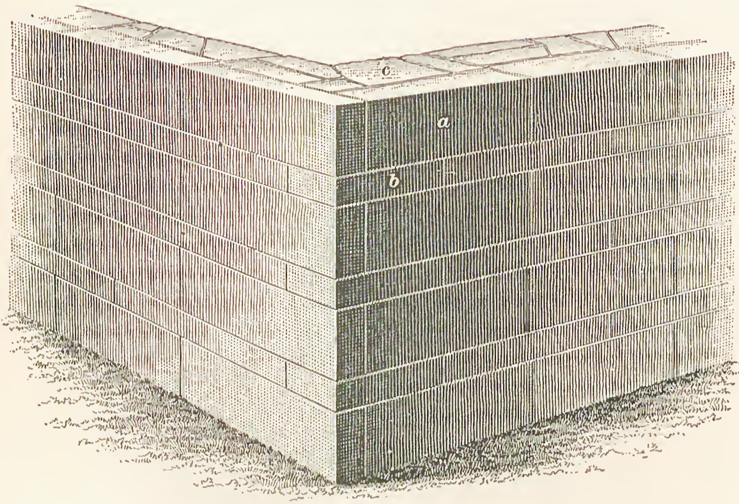


Fig. 25

expensive. A coursed-ashlar wall is shown in Fig. 24, in which 12″ × 36″ ashlar is shown at *a*, and the backing, which consists of 12-inch rubble, at *b*.

31. A good effect is produced by making the courses of two heights, but cut in regular sizes, and having the vertical joints in alternate courses directly over one another. This class of work is illustrated in Fig. 25. In this figure, a 14-inch course is shown at *a*; a 6-inch course, at *b*; and the backing, at *c*. The latter may also be brick, as the ashlar can be well bonded into it. If the narrow band course *b* is rock-faced, or

has some different finish than the wide courses *a*, the appearance of the work will be further improved.

32. The stonework of many public and office buildings has rustic quoins and base or band courses, as shown in Fig. 26. Here, the quoins, which have a 1-inch bevel, or chamfer, at the joints, are shown at *a*; the plain, rubbed, or tooled stones forming the face of the wall, at *b*; the rustic band course, having a $1\frac{1}{2}$-inch chamfer cut on it, so as to project beyond the quoins, at *c*; and the stone or brick backing, at *d*. This

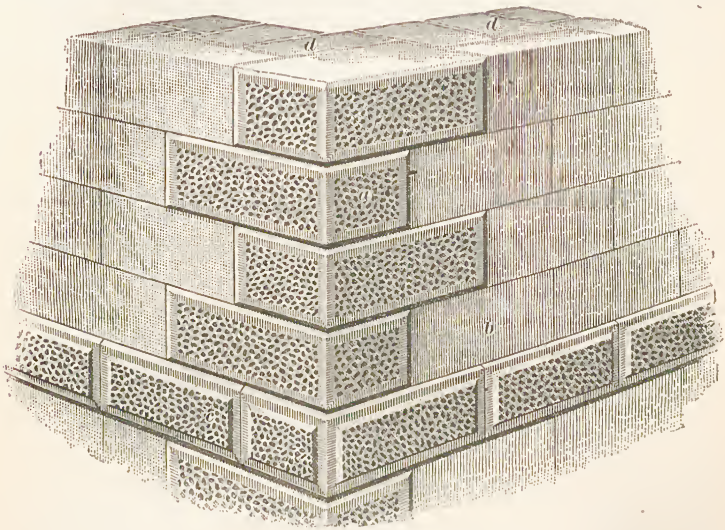


FIG. 26

method of construction is very expensive, owing to the great amount of dressing required.

33. Block-In-Course Ashlar.—In **block-in-course**, or **blocked-course, ashlar work,** all blocks of stone are cut the same height but in different lengths, and no attempt is made to have the joints come over one another. The length on the face is usually two or three times the height, and about one-fifth of the face should show headers, as at *a*, Fig. 27. These headers should rest on long stretchers below them, in order that the wall may be better bonded. As a

rule, this style of work looks best in rock-faced finish, but any finish desired may be used. Many quarries have stratified

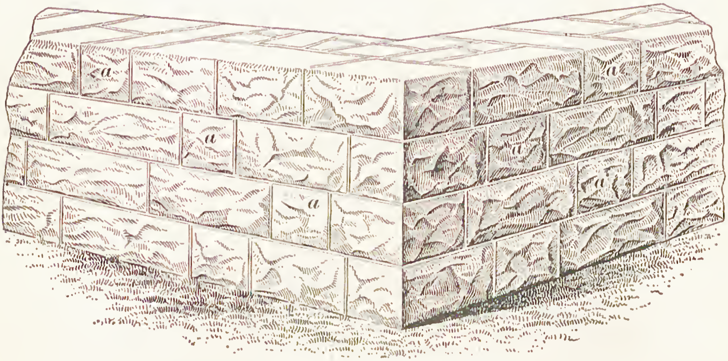


Fig. 27

stone that is just the proper thickness for this class of work, but unless the stone can be found in such shape, block-in-course ashlar work is generally quite expensive.

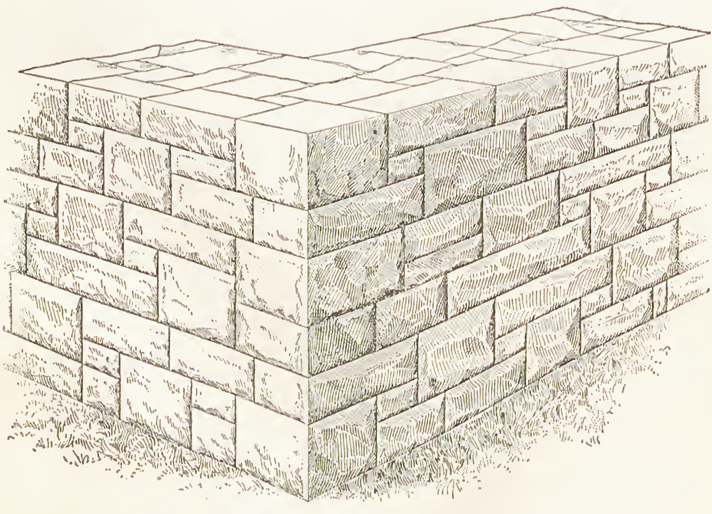


Fig. 28

34. Random-Coursed Ashlar.—The method of laying **random-coursed ashlar walls** is illustrated in Fig. 28.

In this class of work, no attempt is made to have the vertical joints over one another, and it has only a general arrangement in courses, as shown.

In regard to the best methods of proportioning the blocks and arranging the same so as to produce a harmonious effect, it is first necessary to consider what the various heights of the blocks must be in order to form good longitudinal bond. Assume the lowest height at 4 inches—as a stone any thinner than this presents an appearance of weakness—and the greatest height at 16 inches—as any higher than this looks too heavy for random-coursed ashlar. The gradations may then be 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, and 16 inches,

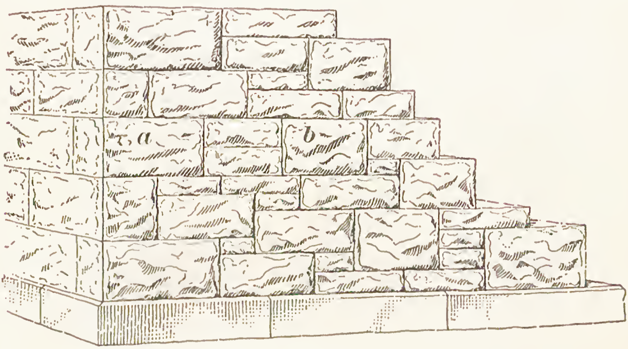


FIG. 29

thus giving eleven distinct heights—a variety that, when well arranged, produces a most pleasing effect.

If the three highest numbers are taken as *jumpers*, or course levelers, combinations may be made of the other stones so that their combined thickness will equal that of the jumper. In this manner, several arrangements are possible.

The next point to be considered is the lengths of the blocks. The bond, or the lap of the stones over one another, should be, for the thinner blocks, at least 6 inches, and for the thicker ones, 8 inches.

35. Broken Ashlar.—In **broken-ashlar stonework,** no attempt is made to have the stone run in courses, but each block is cut for the location in which it is to go. It

generally takes more time to build broken ashlar than coursed work; hence this kind of wall is more costly, owing to the increased amount of labor required to fit and lay the different sizes of stone. Broken ashlar, when properly executed, presents a pleasing appearance. It is generally laid up as rock-faced work, but in some cases, it is tooled or hammer-dressed. It should have no horizontal joints more than 4 feet long, and several sizes of stone should be used. Fig. 29 shows an ordinary broken-ashlar wall, 2 feet thick, the sizes of stones used being 4, 6, 8, and 12 inches in height. The quoins are shown at *a*, and the body of the wall at *b*.

36. Best Stone for Ashlar.—The hardest kinds of rock are best suited for ashlar masonry, as, in pitching, the spalls fly off more easily and leave the fracture in sharp lines; whereas, with the softer kinds of rock, the fracture has a bruised and crushed appearance, which is not at all pleasing. The best stones to use are the granites and the most compact bluestones and sandstones.

37. Laying Out Ashlar.—If ashlar in regular courses and sizes is to be used, drawings should be made showing each stone of different size, the heights of the courses, and other necessary details. The drawings for public and office buildings usually show every stone, unless broken ashlar is used, in which case it is only necessary to show the quoins and jambs, together with enough of the ashlar to indicate the character of the work desired. It is almost impossible to follow carefully a drawing showing all the stones laid as broken ashlar.

38. Backing.—The expense of ashlar masonry is such that it is commonly used merely as a facing, being backed with either rubble masonry or brickwork. It is only on works of great importance and solidity that ashlar masonry is used throughout the whole thickness of the wall. In general, the term ashlar applies to the facing, or veneering, of stone, or to the stones that constitute the facing.

Both stone and brick are used as backing, but in most cases, brick is the cheaper and is therefore more extensively employed. When using brick for the backing, the joints should be made as thin as possible, employing cement mortar so as to avoid shrinkage. Backing of this kind, however, should never be less than 8 inches thick.

When a hard, laminated stone with flat, parallel beds can be obtained, it should be used, as it is considered to be a stronger backing than brick. Irregular rubble backing should not be used for dwellings higher than two or three stories, unless the walls are made at least one-fourth thicker than

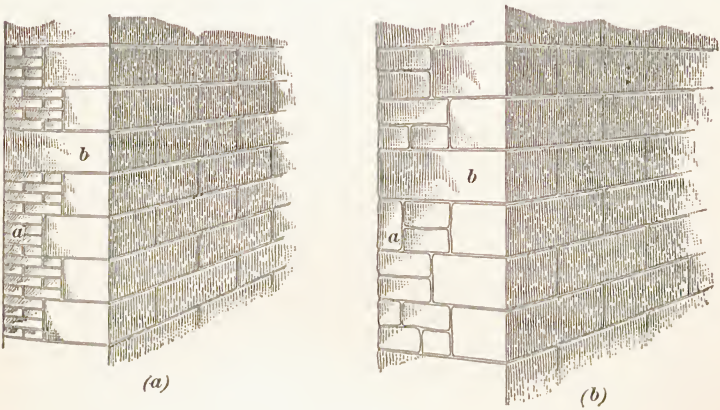


Fig. 30

when brick backing is used. All backing, whether of brick or of stone, should be carried up at the same time and built in courses of the same thickness as the ashlar. This kind of construction is illustrated at *a*, Fig. 30 (*a*) and (*b*).

If the courses are not over 12 inches high, they are usually bonded sufficiently to the backing by making every other course wider, and by having one through bond stone to every 10 square feet of wall, as shown at *b*, Fig. 30 (*a*) and (*b*). This method is called a *toothed bonding*.

39. Method of Fastening Thin Ashlar.—Although not so strong as a toothed bond, an ashlar facing of from 2 to 4 inches in thickness is often used, especially when marble or

other expensive stones are employed in the construction. In such cases, each piece of ashlar should be tied to the backing by at least one *iron clamp*, or *anchor*, similar to that shown in Fig. 31, while if the stones are more than 3 feet long, two anchors should be used. All iron clamps, or anchors, should be either galvanized or dipped in hot tar or asphalt, to prevent the formation of rust on them.

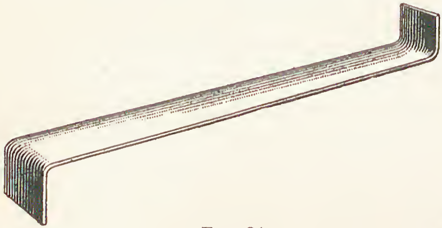


Fig. 31

Belt courses extending 8 inches or more into the wall should also be laid about every 6 feet in height, so as to give support to the ashlar. When a wall is faced with thin ashlar, the effective bearing strength is only that given by the thickness of the brick or stone backing, the facing not being relied on for that purpose.

CARE OF STONEWORK

40. Pointing.—The effects of the weather on the exposed edges of the joints in masonry usually cause the mortar to crumble and fall out. For this reason, it is customary to refill the joints to a depth of from ½ to 1 inch, with specially prepared mortar. This operation is called **pointing.**

In work that is to be pointed, no mortar should be placed within an inch of the front edges of the stone, as this saves raking out the joints preparatory to pointing. Sometimes, strips of wood the exact thickness of the joint are set on the edges of the lower course. Then, in setting the stone, the superfluous mortar is pressed out and the stone rests on the wooden strips, which are removed when the mortar is hard.

Pointing is generally done as soon as the walls are completed, but, if the season is too far advanced, it should be deferred until spring. Under no circumstances should point-

ing be done in freezing weather, nor in extremely hot weather, as then the mortar will dry too rapidly.

The most durable mortar for pointing is made of equal parts of Portland cement and sand. These materials are mixed with just enough water to give a plastic consistency, and to this mixture are added a little slaked lime to make the mortar stick and such coloring matter as may be desired.

Portland and Rosendale cements discolor most limestones and marbles, and some sandstones. However, by exercising care, the mortar may be kept from the face of the stone, and the joints may be pointed afterwards with mortar that will not stain. A cement made of plaster of Paris, lime, and marble dust, called *Lafarge cement*, is sometimes used for setting marble and limestone; it is claimed that this cement will not cause discoloration.

41. Cleaning.—After pointing, it is usually necessary to remove the mortar stains, etc. from the face of the wall. This may be done by scrubbing the stonework with water containing muriatic acid, the proportions being about 20 parts of water to 1 part of acid. For cleaning granite and limestone, wire brushes are used, and for sandstones and other soft stones, stiff bristle brushes usually serve the purpose. The stonework should be scrubbed until all mortar stains are removed.

As previously stated, the sand blast, operated by either steam or compressed air, does the work of cleaning walls very effectively and rapidly. It not only removes the outer layer of the discolored stone, but leaves a fresh, bright surface. Even fine carvings have been very successfully cleaned by this method.

42. Stone Defects.—Granite may contain cracks, black or white lumps known as *knots*, and a brownish stain called *sap*. When such defects are found, the stone should be rejected, provided the importance of the work justifies it. Cracks are the main things to guard against, however, and they may be detected by the absence of the clear ringing sound when the stone is struck with a hammer.

Sand holes are frequently found in sandstones. These are bodies of uncemented sand, that become dislodged by jarring or by the action of water, and produce a pitted appearance and an uneven color. Attention must also be paid to securing uniformity of color, as sandstone from different parts of the same quarry may vary greatly in this respect.

43. Faults in Dressing Stone.—The common faults of cut stone are coarseness and poor workmanship. In dressing stone, builders will avoid any work beyond that necessary to make the material barely acceptable to the inspector.

Frequently, the ends of cornices, belt courses, etc. will not match properly. It should be strictly required that the utmost care be taken in cutting all similar pieces to the same pattern, and that the abutting surfaces be closely dressed.

44. Laying of Stonework.—In erecting stonework, care should be exercised to have the stone set on the natural bed, with good joints, and not in too small nor in too thin pieces. The bed joints in ashlar work should be square to the face of the work, and not less than 4 inches wide at both top and bottom. The proper bonding of the walls, especially for the ashlar and for the trimmings, should be given very careful attention, as should also the placing of lintels, copings, wall anchors, etc.

Another point that requires attention is the formation of the joints on which great pressure comes; also, the mortar should be kept back from the face, so that the edges of the stones will not be chipped off. In pointing, the joints should be well raked out and the pointing mortar properly laid. Many other precautions for the good performance of the work will doubtless suggest themselves to the careful superintendent.

TRIMMINGS

SPECIAL STONES

45. The term **trimmings**, as generally used, includes moldings, belt course, sills, caps, and other cut stone (except ashlar) used for ornamental purposes.

The stones for such work should be of good quality, having the beds closely dressed and the ends square and properly matched. The faces may be pitched off, but all washes, soffits, etc. should be cut or rubbed. When a brick building is trimmed with stone, great care should be taken to have the trimmings set properly, so that it will not be necessary to split the courses of brick below or above, for such a procedure will spoil the appearance of the building.

46. Bond Stones and Templets.—All piers above a certain size require **bond stones**, that is, stones the full size of the pier, to prevent them from splitting. The course of brick placed underneath should be brought to an exact level to receive the stone; otherwise, the weight above may cause it to crack or become displaced. Only strong stones, such as granite, bluestone, and hard trap rock, should be used, and they should be cut to the full size of the pier.

47. Bearing stones placed under the ends of beams and girders to distribute the weight more evenly on the wall are called **templets.** The pressure per square inch allowed on the brickwork or stonework in the wall under the templet, as specified by the building laws of the town in which the building is being erected, governs the size of the templet required, and is usually from 100 to 200 pounds. It is better, however, to make templets too large rather than too small. A hard, tough stone should always be employed, and the usual rule is that the thickness of the stone should be one-third of the smallest surface dimension, except when very large stones are used; but the *least* thickness should be 4 inches. When a wooden girder rests on a

templet, a good plan is to place a flat stone *above* the end of the girder, so that the wall will rest on the stone and not on the wood. This is advisable for the reason that when the wood shrinks the settlement may cause cracks in the wall.

Strictly construed, bond stones and templets are not ashlar; but as they require more or less dressing, they are considered as being ashlar.

48. Quoins.—The corner stones of a wall, as already inferred, are known as **quoins.** They are often dressed

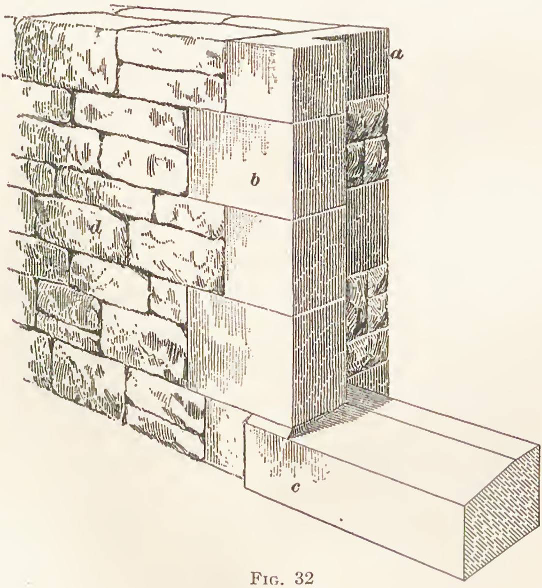


FIG. 32

differently from the other stones in order to make them more prominent. Quoin stones should always be equal in size to the largest stone used in the wall; otherwise, the effect of strength and solidity that they are intended to produce will be lost. Sometimes, the quoins of a rubble-stone wall are built of brick.

49. Jamb Stones.—The stones used in the sides of a door or window opening are called **jamb stones.** The alternate ones should extend through the width of the wall to

insure a good bond. Fig. 32 illustrates cut-stone jambs in a rubble wall. The jamb stones bonding into the wall transversely are shown at *a*; those bonding longitudinally, at *b*; the stone window sill, at *c*; and the rubble wall, at *d*.

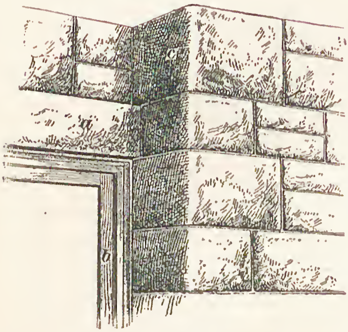


FIG. 33

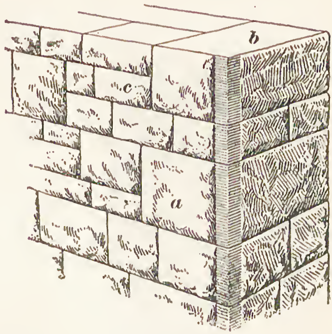


FIG. 34

50. Occasionally, when stone piers or pilasters are built on the outside of the building, the windows are recessed so that the projection of the sills and lintels will not be so

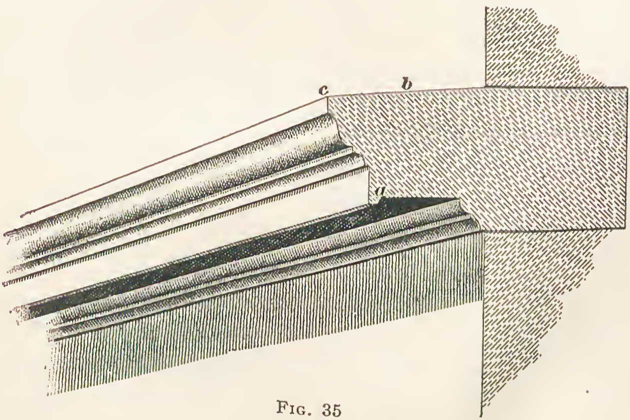


FIG. 35

noticeable. This is illustrated in Fig. 33, in which *a* shows the lintel; *b*, the sash; and *c*, one of the jamb stones.

Jambs and quoins are often finished with a draft, or angle, line, especially when the softer stones are used. Fig. 34

illustrates this method of finishing, the quoin or jamb stone, as the case may be, being shown at *a*; the angle draft, at *b*; and the broken ashlar wall, at *c*.

51. Washes and Drips.—The tops of all cornices, belt courses, etc. should have an outward and a downward pitch from the walls, as shown at *b*, Fig. 35. If the top is level or slopes inwards, rain will collect, and in time will cause the disintegration of the mortar in the adjacent joints and finally penetrate the wall. The beveled surfaces are called **washes.** On the under side of the cornices, etc., **drips** should be made, to prevent rain water from flowing down the face of the wall. At *a*, Fig. 35, is shown the drip; at *b*, the wash of the cornice; and at *c*, the stone cut to a sharp angle, so as to shed part of the water from that edge.

Fig. 36

Window sills should also have a drip cut in them, as shown at *a*, Fig. 36, so as to keep the walls below from becoming discolored by dirt washed off the sills by rain.

LINTELS

52. A **lintel,** often called a *cap*, is a stone that supports the wall over a door or a window opening; and, as it must resist bending stress, it should be a strong, tough stone having an ample cross-section. The ends of stone lintels should not be built into the walls more than is necessary to give sufficient bearing; 4 to 6 inches at each end is the usual allowance. There should be a little play allowed at each end, so that the lintels can yield slightly without cracking if the walls on either side settle unevenly.

53. Relieving Lintels.—Often, when a long lintel is used over an opening, the stonework above the lintel is arranged as illustrated in Fig. 37, in which *a* shows the lintel, and *b* the **relieving lintel,** or stone above it cut with

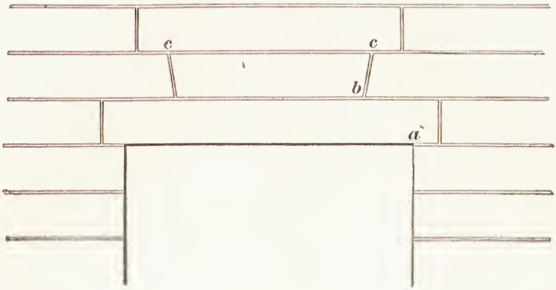


FIG. 37

two diagonal joints, as at *c*. In this way, some of the load is taken off the lintel and transferred to the wall on both sides of the opening.

When a lintel extends through the wall and is not supported by angles or beams, the strength may be increased, provided the stone is stratified, by cutting it in such a manner

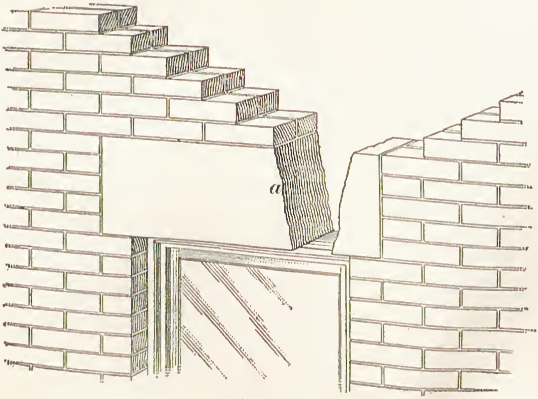


FIG. 38

that the layers will set on edge, as shown at *a*, Fig. 38. This procedure, however, may cause the face of the lintel to flake off if the layers of stratification are thin and not securely joined together.

54. When considerable weight rests on a stone lintel, a brick relieving arch may be used; but unless much skill is exercised in its construction, this arch will detract from the appearance of the building, especially if it extends through the entire thickness of the wall. To avoid this result, if stone of sufficient depth cannot be used, the lintel may be strengthened by the use of iron beams or angles. When the lintel is of moderate length, it is sufficient to use a piece of angle iron, as in Fig. 39, in which *a* shows the stone lintel; *b*, the angle, which should have its longer side vertical; *c*, a wooden beam to which the interior woodwork is nailed; *d*, the brick wall; and *e*, the window reveal, or side.

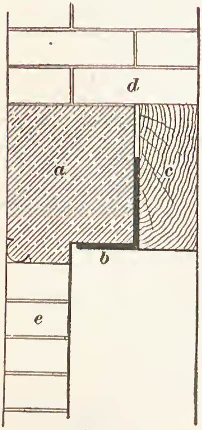


FIG. 39

55. I-Beam Supports.—When the width of the opening is considerable, stone lintels should be supported on **I** beams.

FIG. 40

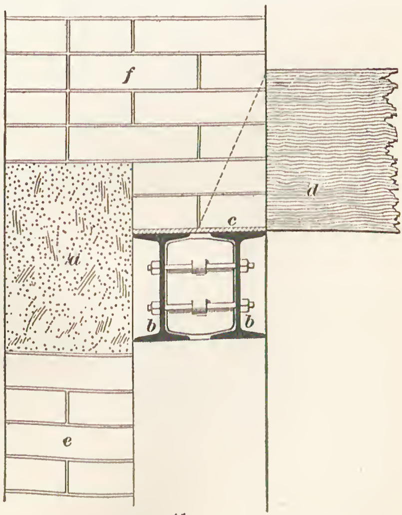


FIG. 41

If only the weight of the lintel and wall is to be carried, a single **I** beam may be used, as shown in Fig. 40, in which the

stone lintel is shown at a; the **I** beam, at b; the wooden beam to which the wood finish is attached, at c; the reveal, at d; and the brick wall, at e.

If, in addition to the walls, the floorbeams over openings must be carried, it is best to use two **I** beams, as in Fig. 41. Here, the stone lintel is shown at a; the **I** beams, held together by bolts and separators, at b; an iron plate on which the wall rests, at c; a floorbeam, at d; the window reveal, at e; and the brick wall, at f.

When it can be avoided, the best plan is not to support the weight of a wall on both stone and steel or wooden beams, as the deflection of each material is different, making it practically impossible for each to carry its proper share of the load. The weight should preferably be borne by the steel beams alone.

56. Built-Up Lintels.—It is sometimes necessary to use a stone lintel that is 10 or 12 feet long. Since it is difficult to obtain a single piece of stone of this length, the lintel may

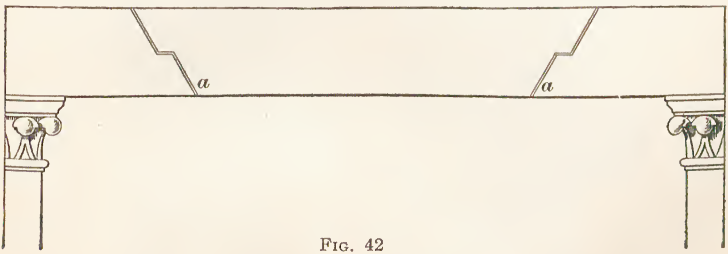


Fig. 42

be made in sections, as in Fig. 42. At least three stones should be used, and the joints should be cut as shown at a. When cut in this manner, the stones are self-supporting. The end pieces may be built into the wall for a considerable length, so as to act as cantilevers supporting the middle section. If such long lintels are used, however, it is better to carry them on **I** beams, as shown in Figs. 40 and 41.

In stonework it is best to avoid placing a pier directly on top of the lintel; all openings should preferably be directly above one another.

SILLS

57. Lug and Slip Sills.—In masonwork, **sill** is the name given to the stones that form the bottom of the window and door openings in stone or brick walls.

Lug sills have flat ends, or *lugs*, built into the wall. These lugs should not enter the walls a distance of more than 4 inches, and should be bedded on mortar only at the ends. If a sill is bedded solid and settlement occurs, it will probably be fractured at the jamb line, as the pier or side walls will likely settle more than the wall under the opening. The

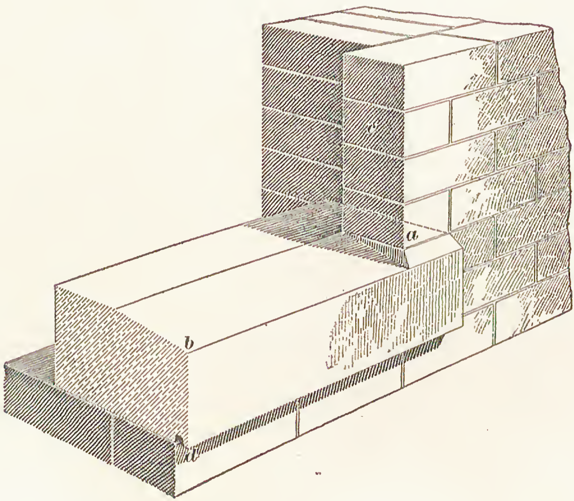


FIG. 43

joints under the sills should be filled when the finished walls are cleaned down.

Slip sills are made just the width of the opening, and are not built into the walls, being put in place after the frame is set. Such sills are cheaper, but they do not look so well as lug sills; besides, there are exposed vertical joints at the ends into which water will penetrate. However, any settlement of the masonry is not liable to break a slip sill, and they are therefore often used in the lower parts of heavy buildings.

58. All sills should have a bevel, or wash, about 1 inch to the foot, extending to the back of the reveal, as shown in Fig. 43. They sometimes have a beveled surface the full length of the sill, the brickwork being made to fit the stone. The latter construction, however, is not good practice, as it permits water running down the jamb to enter the joint between the brick and the stone; the sloping upper face also forms an insecure bearing for the wall resting on it. In Fig. 43 is shown the proper method of cutting the surfaces. As shown at *a*, the flat end of the lug sill carries the brickwork reveal *c*. At *b* is shown the bevel, or wash, and at *d*, the drip.

COPING

59. If no cover is put on the top of a wall, rain will wash out the joints. For this reason, parapet walls are capped

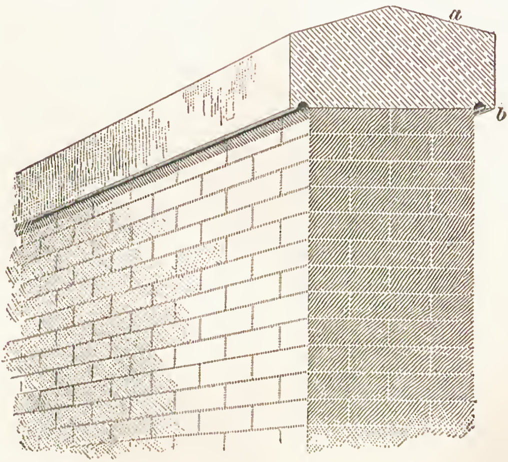


Fig. 44

with a wide stone called **coping.** Terra cotta is also occasionally used for this purpose. The upper surface of the coping should be pitched, as shown at *a*, Fig. 44, and should have a drip on the under side, as shown at *b*. The coping should be about 3 or 4 inches wider than the wall. Horizontal coping stones are often clamped together at their ends to prevent them from becoming displaced.

Gable copings should be anchored either by bond stones or by long iron ties. A form of coping that is extensively

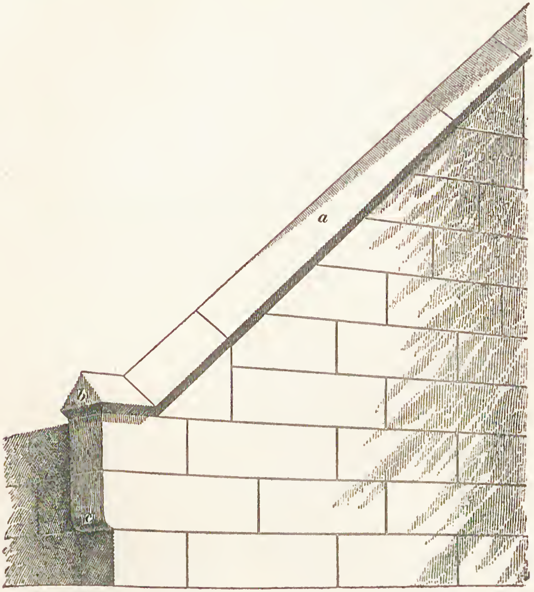


Fig. 45

used is shown in Fig. 45, in which the coping is shown at a, and the corbel, at c. The bottom stone b, sometimes known

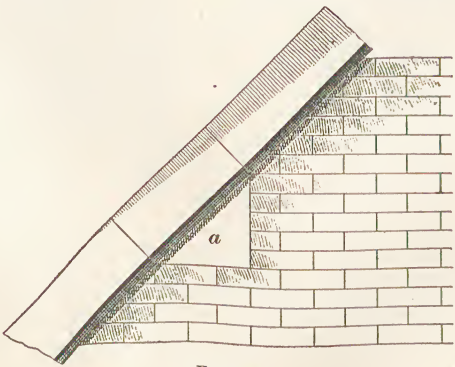


Fig. 46

as the *kneeler*, should always be well bonded into the wall. In some cases, the coping is cut in steps, so that each stone

will have a horizontal bearing on the wall. This method of coping is objectionable, however, on account of the increased number of joints. It is well to have long pieces of coping, so as to reduce the number of joints—a common length is 6 feet. A short piece of coping cut as shown at *a*, Fig. 46, should be inserted at intervals to bond the coping securely to the wall.

Gable copings do not necessarily have to be pitched on top, but they should project on both sides of the wall and should have a drip at each edge so as to shed rain water.

STONE STEPS

60. In laying **stone steps**, it is important to see that they are firmly supported at each end, but left free in the middle. If the stones forming the steps have a bearing along

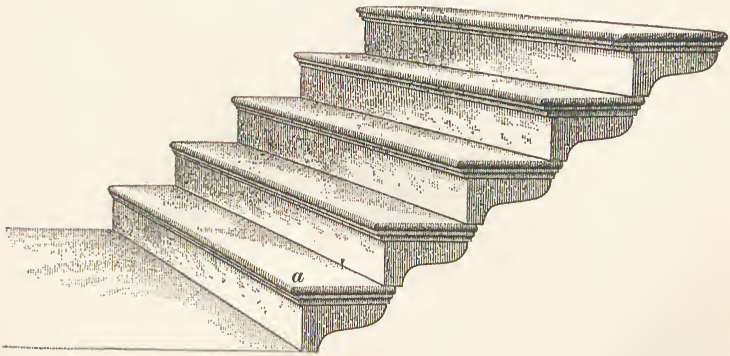


Fig. 47

their entire length, they might, after a slight settlement in the foundations, rock from side to side when stepped upon, or they might crack. In order to strengthen extra long steps, however, it is sometimes necessary to insert a middle bearing; great care must then be taken to have the middle and two end supports exactly on a line. Each step should overlap the one below at least $1\frac{1}{2}$ inches, and should have an outward pitch of about $\frac{1}{8}$ inch. Steps having a nosing, as shown at *a*, Fig. 47, make a good appearance, but they are more expensive than the ordinary steps.

A hard stone, such as granite or bluestone, should be used for steps; but for private residences, where the wear is not great, limestone or a fairly hard sandstone may be employed.

61. Stone stairs are sometimes made with only one end supported. This end is built solidly into the wall, and each step is carried on the next lower one, as illustrated in Fig. 48. As shown at *a*, the landing is rabbeted into the tread of the top step. The manner in which each step is cut and supported by the lower one is shown at *b*. To be safe, the bearing dimensions should not be less than are indicated in the illustration. The bottom step should be firmly held in place by

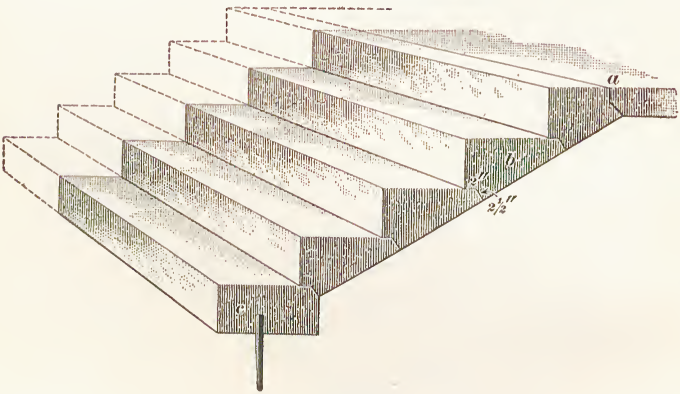


FIG. 48

dowels set into the floor, as shown at *c*, as this step must sustain the thrust of the whole flight. The stone blocks forming the steps are usually cut in the triangular cross-section shown, which method of cutting gives a good appearance to the soffit, or ramp, of the stairs.

62. Iron staircases are extensively used in fireproof construction. In such cases, the treads, and sometimes the risers, consist of marble slabs, while slate, which is cheaper, is also used. Staircase railings for stairways having stone or iron steps are often elaborately finished. They are generally made of iron, which is doweled into the ends of the steps.

FOOTINGS

PURPOSE OF FOOTINGS

63. If a man stands on soft mud, marshy ground, or quicksand, he sinks to a greater or less depth, proportional to his weight. If, however, he stands on a plank or a wooden platform, or on a post or posts driven through the mud or marsh to firmer ground, his weight is distributed over a larger area in the first case and carried down to a better foundation in the second.

The same thing is true of the **footings** of buildings. By spreading the load, or weight of the structure, over a larger area or bearing surface, the weight of the building is more evenly distributed, and the likelihood of a settlement, due to compression of the ground, is greatly diminished. For this reason, the higher and heavier the building is to be, the wider and deeper the supports or footings for the foundation must be; and if extremely soft or yielding ground is encountered, piling should be resorted to in order to carry the weight of the building to a more solid base.

64. Footings may be of iron, timber, or large, flat building stones laid directly on the ground or on a bed of concrete, or they may be of concrete alone or with reinforcement, or of concrete and stepped-up brickwork. Where piling is used, heavy capping timbers are often placed on the heads of the piles, with either stone or concrete footings resting on them; or large footing stones may be laid directly on the piles.

TIMBER FOOTINGS

65. Timber is often used for footing courses where a large bearing surface is necessary and can be obtained, provided, always, that the timber can be kept from rotting. In some cases, the timber is charred on the outside; and, again, it is coated with asphalt. If the ground is continually wet, there is little to fear, as timber will not decay when kept con-

stantly saturated with water; but when alternately wet and dry, unprepared timber cannot be depended on.

A good method of placing planks under walls for footings is to use $3'' \times 12''$ plank cut in short lengths and laid crosswise in the trench. A layer of plank of the same size is then laid lengthwise, followed by a third layer placed transversely. In Fig. 49, the stone footing *b* rests on the

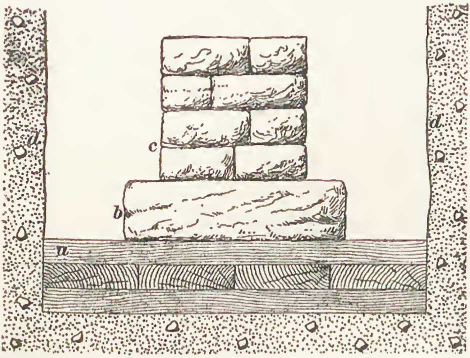


FIG. 49

footing planks *a* and carries the stone foundation wall *c* between the sides *d* of the trench.

CONCRETE AND STONE FOOTINGS

66. Fig. 50 shows a 20-inch brick wall *b* erected on a concrete footing *a* that is 20 inches thick and 36 inches wide. Figs. 51 and 52 show concrete bases *a* and stepped-up brick footing courses *b*. In Fig. 51, each step of brickwork is set back 2 inches for each course, while in Fig. 52, each step is set back 4 inches for each two courses. At *c* is shown a 20-inch brick foundation wall resting on the stepped-up brick footing.

Fig. 53 illustrates a stone footing *a*, composed of three courses of flat stone, each course being 8 inches thick. The top course projects 6 inches on each side of the 20-inch brick foundation wall *b*, and the middle and bottom courses each project 3 inches making the width of the bottom stone 3 feet 8 inches.

Fig. 54 shows a stepped-stone footing *a* similar to that shown in Fig. 53, but supporting a 24-inch stone foundation

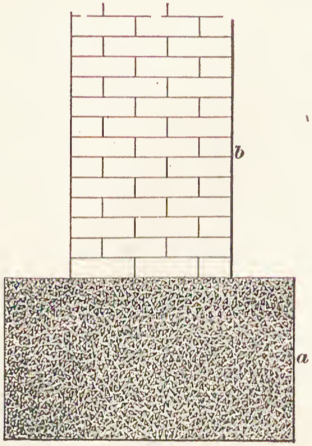


FIG. 50

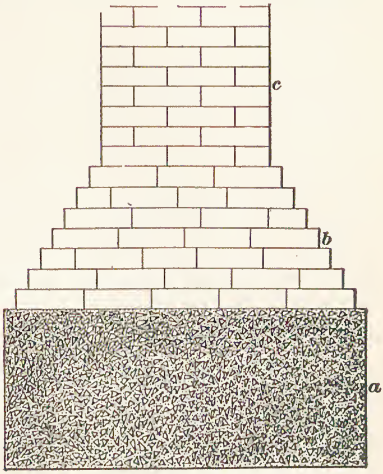


FIG. 51

wall *b*. Each base course advances 3 inches beyond the one above.

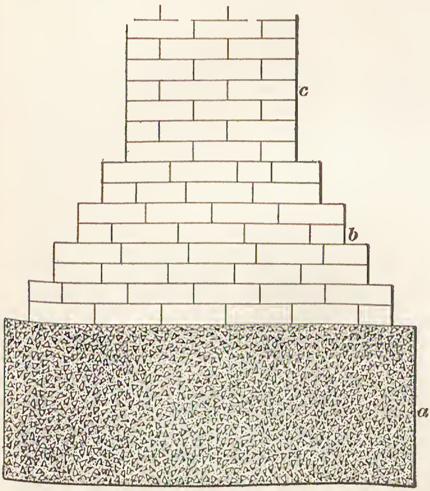


FIG. 52

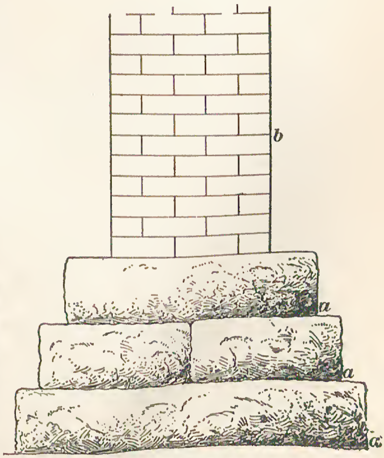


FIG. 53

Fig. 55 shows a footing consisting of a single course of stone *a*, 8 inches thick and 28 inches wide, carrying the stone wall *b*, 20 inches thick.

67. As a rule, concrete, when of sufficient depth and width, and when properly made and laid, makes the best footing course. Concrete for footings should be made of

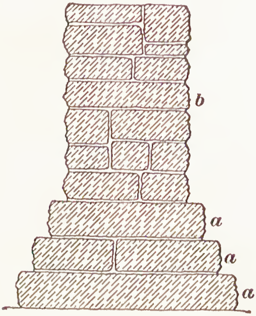


Fig. 54

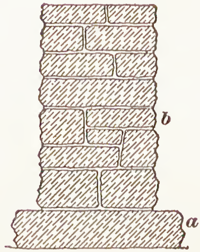


Fig. 55

1 part of good cement, 3 parts of clean, sharp sand, and 6 parts of sharp, broken stone. In very important work, such as bridge piers and the footings of very tall buildings, chimneys, etc., a mixture consisting of 1 part of cement, 2 parts

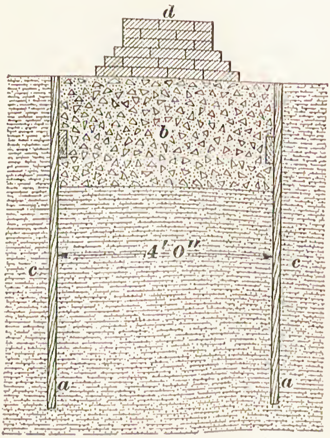


Fig. 56

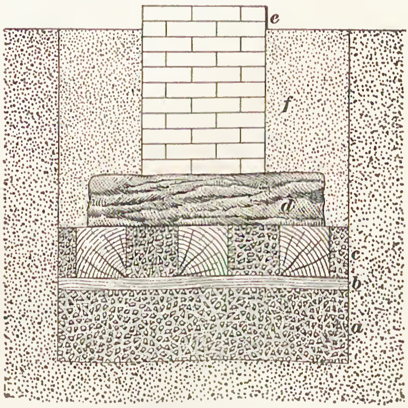


Fig. 57

of sand, and 4 parts of broken stone is sometimes used. The New York building laws call for 1 part of cement, 3 parts of sand, and 5 parts of broken stone.

In localities where stone cannot readily be obtained, broken brick or terra cotta may be used in the same proportion as stone, but care should always be taken to use good, hard-burned material.

Well-broken foundry slag and scoriæ, clean steam-boiler ashes from anthracite coal, and clean-washed gravel, mixed in the proportions given, also make good concrete.

68. Quicksand, when confined, can be safely built on. Fig. 56 shows a method of confining quicksand by sheet piling and placing concrete between the piling. In this case, the sheet piling shown at *a* is placed 4 feet apart. The concrete, shown at *b*, is 2 feet thick and extends the full width of the piling. The quicksand, through which the sheet piling is driven, is shown at *c*, and the 20-inch brick foundation wall, at *d*.

69. Fig. 57 illustrates a footing composed partly of timber. The footing from which this was taken was placed near the water-line of a marsh in New York state, to carry a factory building 50 ft. × 80 ft. and 40 feet high. The soil was a stiff, black muck, and at a depth of about 5 feet, water-soaked sand was found. After the trenches were dug, a bedding of concrete *a* 12 inches thick was laid. On top of this concrete, 2-inch spruce planks *b* were placed crosswise, followed by 8″ × 8″ timber *c*, laid parallel, with the trenches filled in between with concrete. On these planks and concrete were laid the base stones *d*, and on top of these stones was built a 20-inch foundation wall *e*. The trenches on each side of the wall were filled in with sand, rammed down, as shown at *f*.

This factory building contains an engine, shafting, boiler, and machinery, and, besides, over one hundred employes are constantly at work, yet no settlement has occurred, though it has been built a number of years.

70. Stone-footing courses should be laid with large flat stones not less than 8 inches thick. If more than one course is laid, the joints should never come over each other, as that

would defeat the object of bonding, which is to tie together firmly the parts of the wall.

All stone footings should lie on their natural, or quarry, beds, and all joints and spaces between the stone must be well filled with mortar. The mortar acts as a bedding between the stones, and unless it is interposed, the uneven pressure of one stone on another might cause a fracture of one and produce settlement.

71. All footing courses, as indeed all masonwork below the ground level, should be laid in cement mortar. The usual proportion of cement and sand for cement mortar is 1 part of cement and 3 parts of sand. The proportions just stated are from the building laws of New York, and have been found suitable for general masonwork.

72. Stepped-up brick footings having concrete and stone bases, as shown in Figs. 51 and 52, are often used. The pyramidal form of stepped-up brickwork carries the load of the superstructure more evenly to the footings and reduces the risk of settlement or fracture. Nothing except good, hard, well-burned bricks should be used, and these should be laid in cement mortar, and should break joints—that is, no two joints should come over each other.

SPECIAL FOOTINGS

73. Footings on Rock and Gravel.—In placing foundation footings on rock, it is sometimes found that some portions of the footings will rest on the rock, and others, owing to the diversified character of the surface, will rest on clay, sand, or gravel. The settlement of the foundation walls—and as a necessary consequence, that of the whole building—will then be uneven, as the walls resting on the rock will not settle, while those resting on the sand, gravel, or clay, by compressing the material on which they are carried will settle.

74. Fig. 58 illustrates the method employed to obtain equal settlement. In (*a*) are shown the rock and gravel before leveling or excavating, the clay or sand being shown at *a* and the rock at *b*. It is customary to remove the rock to a certain level, as shown in (*b*). The softer soil *a* is then removed and leveled off, as at *c c*, and a bed of concrete about 3 feet thick, as shown at *d*, is then put down. This concrete is brought to the level of the rock, as at *b b*, and on this base the brick or stone foundation wall *e* is built.

In erecting footings on solid rock, it is not considered necessary to cut the footing bed level over the entire surface

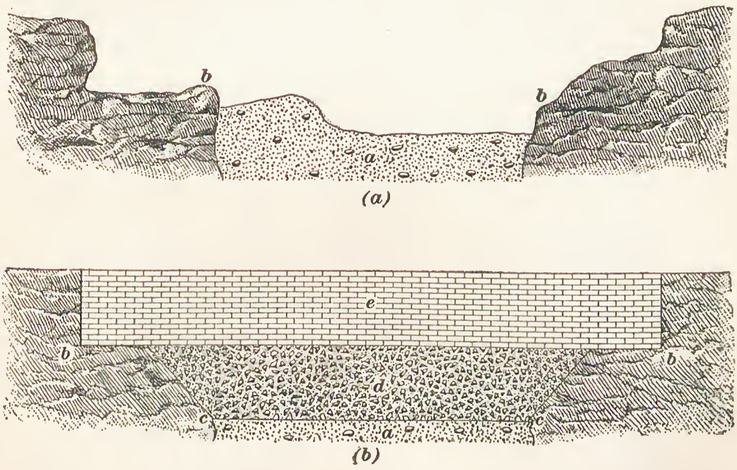


Fig. 58

of the rock, nor even to cut a series of horizontal surfaces resembling steps, as is frequently done in softer soils; but it is necessary to roughen the surface of the rock so as to prevent the footing from slipping on its foundation. After this is done, concrete may be put in to bring the foundation to its proper level. If the structure is to be only three or four stories in height, stone or brick may be used instead of concrete, but a concrete base is usually preferable.

75. Footing on Sloping Ground.—Footing courses built on slopes—especially of clay—are always liable to

slide. This tendency to slide, however, may be overcome by cutting horizontal steps in the slope, as shown in Fig. 59, where the slope *e f* is stepped off, as shown at *a*, in order that

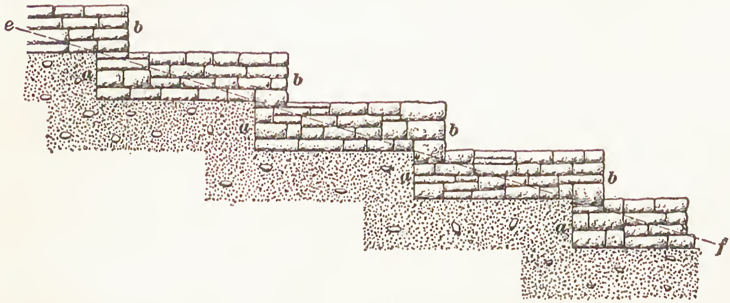


FIG. 59

the footings *b* may have a horizontal bearing. These footings may be either of stone or of concrete, but if the former material is used, great care must be exercised to secure a perfect bond at the stepping places, and the foundations should be laid in as long sections as possible.

76. Inverted Arches.—When a wall is composed of isolated piers, it is well to combine all their footings into one, and to step the piers down, as shown in Fig. 60. In this

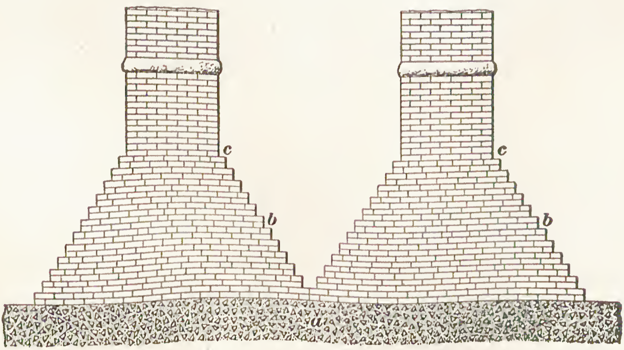


FIG. 60

figure, the concrete footing course is shown at *a*; the stepped-up foundations of the piers, at *b*; and the piers resting on the footings, at *c*.

77. If there is not sufficient depth to step the foundations, use is sometimes made of **inverted arches.** Such arches, however, are to be avoided unless the foundation wall is from necessity very shallow, as great care is required to lay

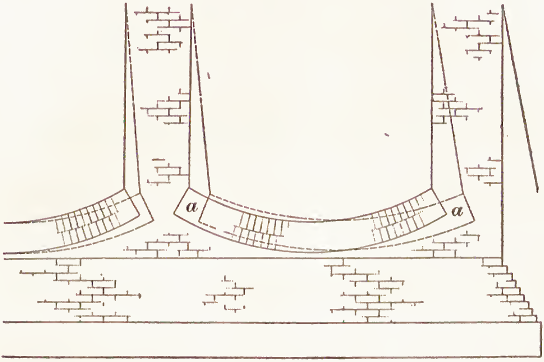


FIG. 61

them properly, and the slightest settlement in the arches has a disastrous effect on the piers.

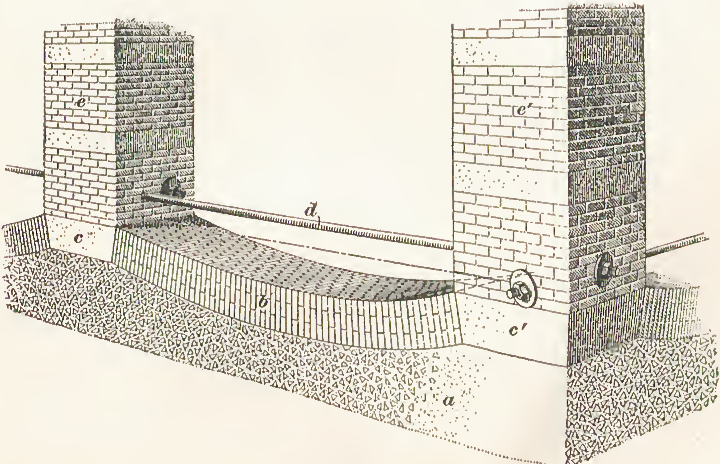


FIG. 62

The end arch of the building must have a pier or other support of sufficient weight or strength to resist the thrust of the arch; otherwise, the weight might throw out the pier, as shown by the dotted lines at *a*, Fig. 61.

This difficulty, however, can be overcome by using an iron rod. with iron plates and nuts, as shown in Figs. 62 and 63, thus securing the skewbacks in place.

The inverted arches turned between the piers should be at least 12 inches thick, or should extend the full width of the piers. They should also rest on a continuous bed of concrete of proper area, and at least 18 inches in thickness; or, they may rest on two footing courses of large stone, the bottom course being laid as stretchers and the top course as headers.

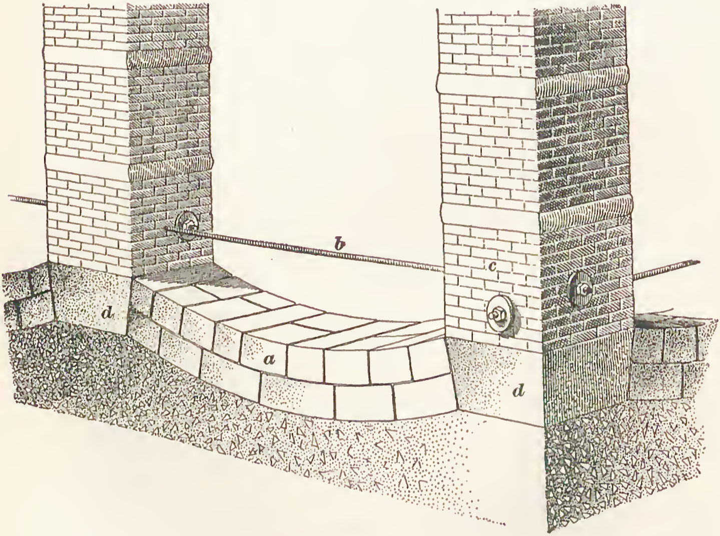


FIG. 63

78. Fig. 62 illustrates two piers, each 3 feet square, connected by a brick-and-concrete inverted arch. At *a* is shown the 18 inches of concrete under the 12 inches of brickwork *b*. At *c* and *c′* are shown the stone skewbacks from which the brick arches spring, and at *d* is shown the 2-inch iron rod that ties the end pier *e′* to the second pier *e*, and thus prevents the thrusting out of the end pier.

Fig. 63 shows an inverted arch built of stone, 24 inches thick. At *a* is shown the stone arch maintained in position by the iron tie-rod *b*, and at *c* the brick foundation piers are shown on the skewbacks *d*.

79. The best form of inverted arch is the *three-centered*, or *elliptic;* next, the *pointed;* third, the *circular;* and lastly, the *segmental arch.*

The method of getting the lines for the centering in an elliptic arch is as follows: Divide the space shown on the line from a to b, Fig. 64, into three equal parts, at d, d; then draw three circles with centers c, so that the circumferences of these circles will be tangent at d. From the center of the middle circle draw the perpendicular $c\,f$; the point f where it intersects the circle is the center of the arch from g to h. From f draw lines $f\,g$ and $f\,h$ of indefinite lengths through

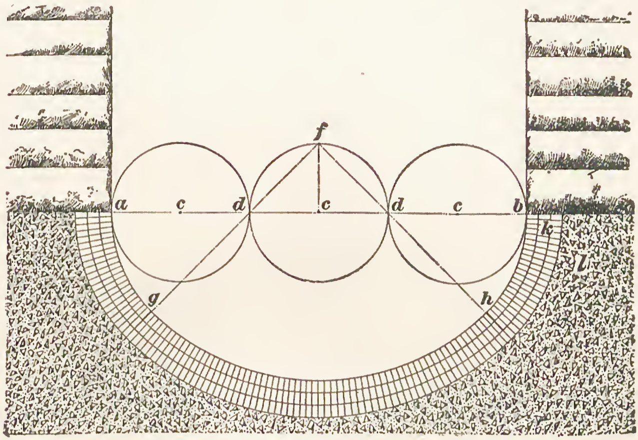


Fig. 64

points d, d. With $a\,d$ as the radius, draw arc $a\,g$ intersecting line $f\,g$ at g. Then, with $f\,g$ as the radius, draw the arc $g\,h$; and from h, arc $h\,d$ with $b\,d$ as the radius.

At k is shown the brick arch, which is 12 inches deep, and at l, the concrete under it. This form of arch is used frequently in the construction of sewers.

THICKNESS OF WALLS

80. Foundation Walls.—A very good rule to fix the thickness of rubble-stone foundation walls is, that they shall be at least 8 inches thicker than the wall next above them, for a depth of 12 feet below grade or curb level; and they should be increased 4 inches in thickness below that point, for every additional 10 feet or less in depth. Thus, if the first-story walls are 12 inches thick, the stone foundation walls would have to be 20 inches thick for 12 feet in depth, and 24 inches thick below that point for 10 feet or less. Rubble-stone foundations walls are seldom made less than 18 inches in thickness. A wall 18 inches thick is not always needed to carry the superimposed weight, but smaller walls are more expensive to build and consequently are seldom constructed.

The thickness of foundation walls in all the large cities is controlled by the building laws. Where there are no existing laws, Table I will serve as a guide.

TABLE I

THICKNESS OF FOUNDATION WALLS

Height of Building	Dwellings, Hotels, Etc.		Warehouses	
	Brick Inches	Stone Inches	Brick Inches	Stone Inches
Two stories	12 to 16	20	16	20
Three stories	16	20	20	24
Four stories	20	24	24	28
Five stories	24	28	24	28
Six stories	24	28	28	32

81. Stone Walls.—The laws regarding the thickness of stone walls differ in the various cities, and no uniform rules can be given. For ashlar work, the New York law states that, "where walls or piers are built of coursed stones, with dressed level beds and vertical joints, the Department of

Buildings shall have the right to allow such walls or piers to be built of a less thickness than specified for brickwork, but in no case shall said walls or piers be less than three-quarters of the thickness provided for brickwork."

The following regulations apply to the District of Columbia for rubblework: "Walls laid with rubblework shall be one-fourth thicker than required for brick walls, but never less than 18 inches thick; they must be constructed with flat stone, sound and durable, laid on their natural beds, and brought to a level every 3 feet in height. They must be built between two lines, shall have bond stone or headers extending through the thickness of the walls at intervals not exceeding 3 feet, and shall be laid in cement mortar composed of 2 parts of sand and 1 part of cement. No rubble wall shall be located as a party wall unless the written consent of the adjoining owner shall first be filed in the office of the Inspector of Buildings. The restriction as to location of the party wall above mentioned shall not apply to stone foundation walls which support brick walls."

For ashlar facing, the requirements for the District of Columbia are as follows: "Thin ashlar facing shall not be counted in determining the thickness of walls. If stone facing is used with bond courses alternately, not less than 8 inches thick, on the beds, then such facing shall be counted as forming part of the wall, and the total thickness of the wall and facing shall not be required to be more than that herein specified for walls (meaning brick) but never less than 13 inches thick."

The thickness of brick walls will be considered in a later Section.

SIDEWALKS

82. Sidewalks may be made of flagstones, concrete, or brick. A **flag** is a thin slab of stone, which is generally used in sidewalk work. Concrete sidewalks are usually finished on top with cement and sand. The bricks used for sidewalk work should be hard and of the variety known as paving brick.

83. Stone Sidewalks.—If stone of a texture that readily splits into flags can be obtained, it will probably make a better and cheaper sidewalk than will concrete. A

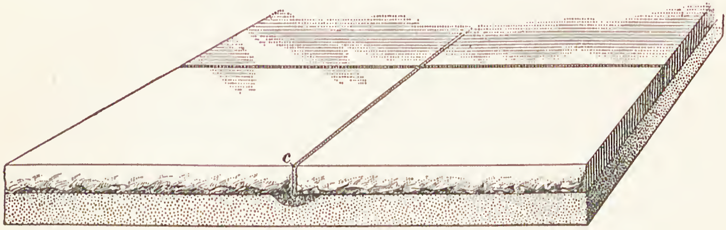


Fig. 65

flag sidewalk can be taken up and relaid better than one of concrete, is easier to repair, and is also more durable.

84. The stone for sidewalks should be 2 or 3 inches thick when used in areas or similar places, and the flags should be cut rectangular. They should be laid on a sand or a cinder bed that is 2 or 3 inches in thickness. The edges of the stones usually rest on a small bed of concrete, or 1-to-1 cement mortar is put into the cracks as shown at *c*, Fig. 65. In this way is obtained a joint that will prevent water from soaking down between the flags and freezing. In countries where there is no frost, this concrete and cement may be omitted, and the sidewalk may simply be laid on the sand bed.

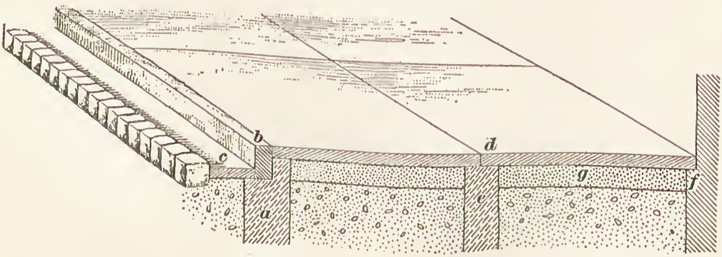


Fig. 66

85. Sidewalks located between the curb and the building line are subjected to more traffic than pavements found in areas, etc. and should therefore be built in a more substantial

manner. The flags used for this class of sidewalks are generally 3 or 4 inches thick. It is always best, if possible, to have the stones of the same width as the sidewalk, but for wide sidewalks this is impracticable. When there is danger of frost getting under the sidewalk and thus causing it to heave, the flags should be supported at the ends only, as shown in Fig. 66. A 12-inch dwarf wall should be built at the curb line, as shown at *a*, and carried below the frost line. The curbstone *b* is from 4 to 6 inches thick, and is rabbeted into the dwarf wall. At *c* is shown the gutter, and *d*, the stone pavement, which is supported at its center by a dwarf wall *e*. If the sidewalk is laid in two courses, or if it extends to the building line, it may rest on a break in the foundation wall *f*, as shown. Under the sidewalk at *g* is a bed of sand or ashes.

86. Brick Sidewalks.—In constructing **brick sidewalks,** good, hard paving bricks, sound and square, should be used. These bricks should be laid flat, herring-bone fashion, on a bed of sand that is from 4 to 6 inches thick. After the bricks are laid and graded, the entire surface should be covered with sand, which is swept over the bricks until the joints are thoroughly filled. If extra thickness of wearing surface is desired, the bricks may be set on edge, and covered with sand as described.

87. Cement Sidewalks.—The method of laying **cement sidewalks** is as follows: The ground should be leveled off from 12 to 15 inches below the finished grade of the walk, and should be well settled by ramming, care being taken that the excavation is drained to one side. A foundation consisting of about 8 or 10 inches of coarse gravel, stone chips, sand, or cinders, should then be laid and well tamped or rolled with a heavy roller. An attempt often is made to economize on this kind of foundation by making it only 5 or 6 inches thick. However, foundations of such thickness generally allow the frost to penetrate to the ground and heave up the pavement in spots.

After the foundation has been rolled, the concrete should be prepared in the proportion of 1 part of cement, 3 parts of sand, 5 parts of broken stone, and a sufficient quantity of water to make a stiff mortar. It should be thoroughly mixed and worked while being laid. The top, or finishing, coat should be laid immediately, and only as much concrete should be laid as can be covered with cement on the same day, because if the concrete gets dry on top, the finishing coat will not adhere to it. The top coat should be prepared by mixing 1 part of the best Portland cement with 2 parts of fine sand or 2 parts of clean, sharp, crushed granite or flint rock.

A ½-inch space should be left between the curb and the pavement and between the building line and the pavement, to allow for expansion and contraction. This space should be filled with cinders or ashes. The pavement itself should be laid off into blocks 6 feet square or less. These blocks should be separated from one another by sheets of tar paper, which should extend all the way through the concrete. It is very essential that grooves be made with a trowel in the top coat directly over the tar paper, so that if the concrete cracks while drying out, it will be sure to part in these grooves and not in the body of the pavement.

88. *Hair cracks* are often caused by the mortar in the top coat being too rich in cement. If the pavement is troweled too much, it has a tendency to make the cement float to the top; this is as liable to cause hair cracks as the use of too much cement. If the top coat is put on too wet, it has the same effect.

89. In many cities, the law requires that concrete sidewalks be finished with a rough surface. Such a surface is not so slippery in winter as a smooth finish; it also possesses the additional advantages that it is easier to construct and does not show any hair cracks. In laying such a surface, the top coat is leveled with a straightedge running on battens, one set on each side of the walk. The battens are arranged so that the part of the walk at the curb will be lower than the

part at the building wall. (This pitch is controlled by city ordinances, and is usually 4 inches in 10 feet for all sidewalks.) The sidewalk is then left until it has almost set, before it is troweled. It should be troweled as little as possible, and with a wooden trowel instead of one made of steel. After troweling, it should be covered with straw and kept moist for at least a week. The less the sidewalk is smoothed with the straightedge or trowel, and the more it is rammed instead, the better it will be.

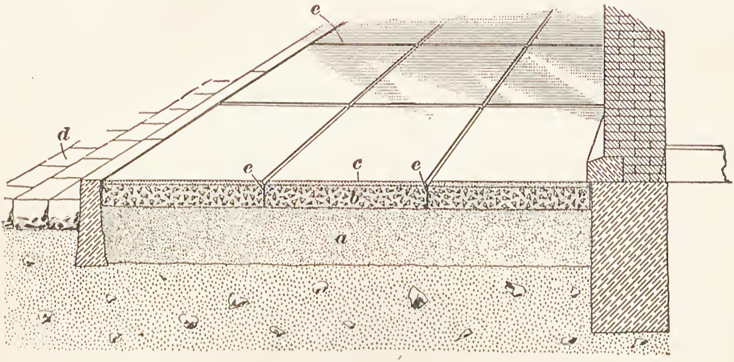


FIG. 67

Fig. 67 shows a section of a concrete sidewalk, the ashes or spalls being shown at *a*; the first coat of concrete, at *b*; the finishing coat, at *c*; the street paving, at *d*; and the joints with tar paper in them, at *e*.

ELEMENTS OF BRICK MASONRY

Serial 1215 Edition 1

STRUCTURE OF BRICK WALLS

METHODS OF LAYING BRICK

DEFINITIONS

1. Bonding.—By the **bonding** of brickwork is meant the process of laying brick across one another so that one brick will rest on parts of two or three bricks below it. When built in this manner, it is difficult for a wall to fail by simply parting at the joints without breaking the brick.

In bricklaying, all corners and joints should be carefully plumbed, the courses of brickwork kept perfectly horizontal—which necessitates uniform mortar joints—and the wall surfaces, both exterior and interior, kept in perfect alinement. All these conditions may have been complied with, and yet the work may be imperfect; the merit of the brickwork must be judged by the thoroughness of the bond observed in every portion of the wall, both lengthwise and crosswise. This bond must be maintained by having every course perfectly horizontal, both longitudinally and transversely, as well as perfectly plumb. Aside from the quality and character of the material, the bonding of a wall contributes most to its strength.

A brick is designated by different terms, according to its position in the wall. When placed lengthwise on the face of the wall, as at *a*, Fig. 1, the brick is termed a **stretcher;**

when placed crosswise with one end only exposed to view, as at *b*, it is called a **header**. A **course** means the vertical thickness of a brick and a mortar joint.

2. Keeping the Perpends.—To obtain the best results in bonding throughout the mass of the wall, strict attention must be given to the location of every joint in the brickwork. On the faces of the wall, the vertical joints in each course throughout the height should be kept perpendicular, or directly over those in the second course below. This is called **keeping the perpends.** The joints across the top of the wall should also be kept in line, so that

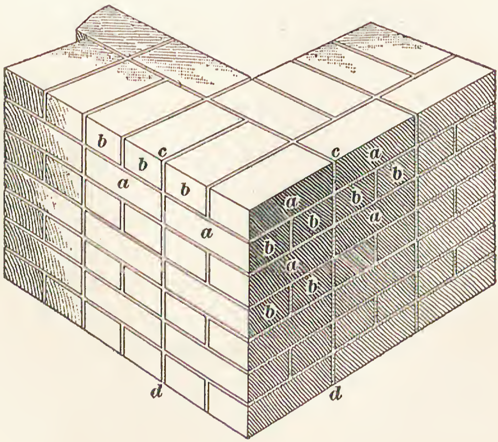


Fig. 1

if the perpends are observed on one face of the wall, the other face will also work up correctly. Even when the wall is exposed on only one face, the importance of having the joints on top of the wall kept in line is just as essential; otherwise, its effective longitudinal bond will soon be lost, since at best the heading bond furnishes a lap of only 2 inches.

3. Necessity of Preserving Bonding.—The importance of having the bond in brickwork preserved in the whole wall can be understood by referring to Fig. 1, which, as already inferred, shows a section of a wall consisting of

alternate courses of stretchers and headers. By placing the brick as shown, no longitudinal bond exists, and the wall is simply a series of contiguous piers that join one another at the vertical lines *c d*, and have no bond or union between them other than that obtained by the adhesion of the mortar. This is because none of the brick in one pier overlaps any brick in the adjoining piers. This method manifestly lacks strength and stability. In order, therefore, to overcome this constructive difficulty and to secure a continuous bond in the length of the wall, recourse is had to a different arrangement of the bricks and also to the use of blocks that vary in size from the ordinary brick.

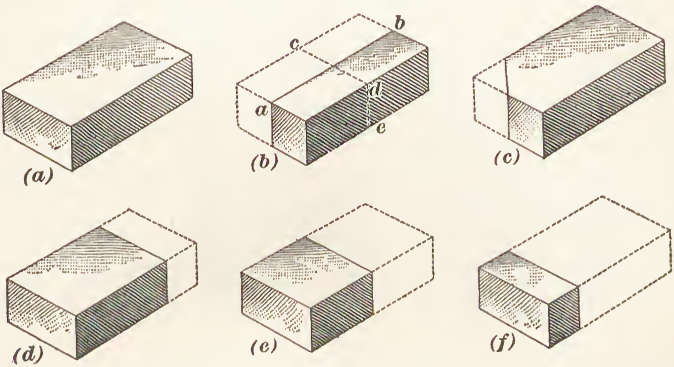


Fig. 2

4. Closers and Bats.—The brick of different sizes used for bonding are called **closers**, the term meaning that they perfectly finish, or close, the length of the courses that have been adjusted to obtain the bond. The vertical joint, which is shown at *c d*, Fig. 1, is avoided, and no two adjacent courses have joints that are immediately over each other. The closers are made by cutting the brick to such dimensions as the situation requires, the operation being performed by striking a brick a sharp blow with the edge of a steel trowel. The cut brick are called **bats**, and are designated according to the proportion that each bat bears to the whole brick. Pressed and enameled brick are often cut with a cold chisel so as to get a more even fracture.

The different bats, or closers, used in brickwork are shown in Fig. 2, (*a*) representing a whole brick of the usual size. If a brick is cut longitudinally, as at (*b*), on the line *a b*, each half is called a **queen closer;** but as it is difficult to cut the full length in this manner, the usual mode is first to cut the brick on the line *c d e*, and then cut each half on the line *a b*. If the brick is cut as at (*c*), it is called a **king closer,** and is a form well adapted for closers at door and window jambs. If one-fourth of the whole length of the brick is cut off, as at (*d*), the remainder is called a **three-quarter bat;** and, in a like manner, the portion remaining at (*e*) is called a **half bat;** and at (*f*), a **quarter bat.**

BOND IN BRICKWORK

5. In connection with the use of closers, whereby the lap is properly secured, there are several methods of placing the brick in the wall, each method having its own name to indicate the kind of bond used.

6. Heading Bond.—When all the courses present the end of the brick in the face of the wall, the wall is then

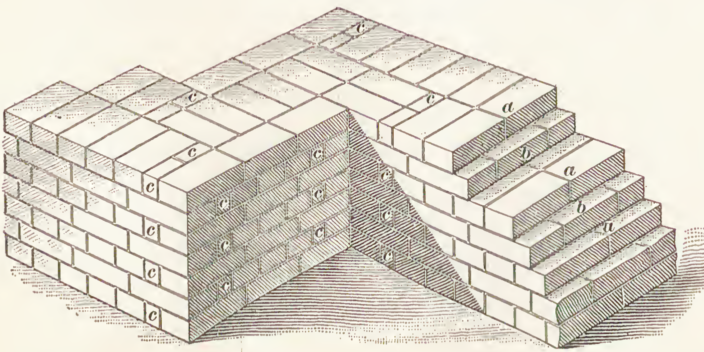


FIG. 3

composed entirely of *headers*, and is known as the **heading bond.** This method of bonding, however, is suitable only for sharp-curved walls, as it possesses little longitudinal bond.

7. Stretching Bond.—When all the courses consist of stretchers, the **stretching bond** is the one employed. The wall formed by this method should be used only for partitions that are not greater than 4 inches in thickness. If the wall is to be thicker, the method should not be followed, as there would be no transverse bond.

8. English Bond.—In the **English bond,** the header and stretcher courses are laid alternately, as shown in Fig. 3. Joints are broken in the longitudinal bond courses by the use of quarter-bat closers, as shown at *c*. The joints can also be broken by the use of three-quarter bats. It will be observed that the heart of the wall consists entirely

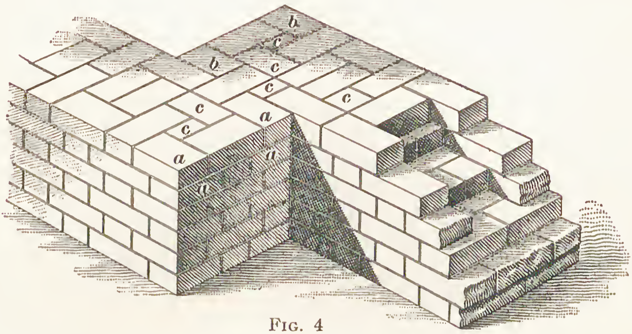


Fig. 4

of heading bond, and that the joints of the heading course, as at *a*, are well bonded by the headers of the stretching course, as at *b*.

9. Flemish Bond.—In the method known as **Flemish bond,** only two-thirds of the number of headers that occur in English bond are exposed, and each course is composed of a header and a stretcher laid alternately. The method of laying the brick in Flemish bond is shown in Fig. 4. The lap in this case is obtained by the use of three-quarter bats both at the external and at the internal angles of the wall, as shown at *a* on the external and at *b* on the internal angles. In Flemish bond, the closers occur in the heart of the wall, just as was shown in English bond; these are quarter, half, and three-quarter bats, as shown at *c*.

By referring to the illustration, it will be seen that, owing to the headers and stretchers being placed on the inner side of the wall immediately opposite those on the outer face, both faces will appear exactly alike when thus arranged. The wall is then said to be built in **double Flemish bond.**

10. Garden, or Running, Bond.—The bond most extensively used in the United States, known as the **garden,** or **running, bond,** is shown in Fig. 5. This bond, which enables the bricklayer to build a larger amount of wall in a given time than does either the English or the Flemish bond, is sometimes called **American bond.** It consists in laying from four to seven courses as stretchers and bonding with a row of headers at regular intervals. The longitudinal lap is secured by closers, as shown at *c*. The heading course in the heart of the wall is shown at *a*, being placed immediately over the heading course *b* exposed on the face.

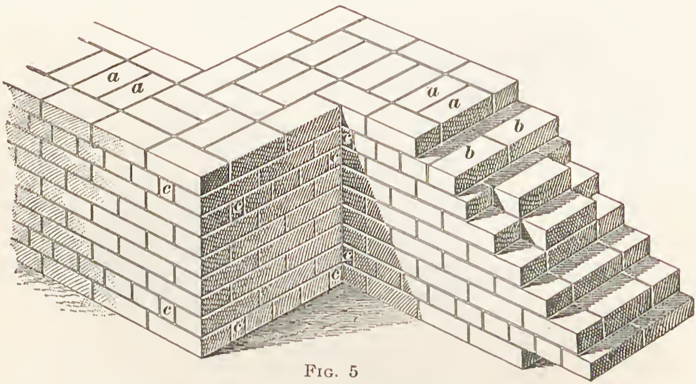


Fig. 5

The principal defect of the running bond is that the wall is practically composed of a series of 4-inch layers from $12\frac{1}{2}$ to $17\frac{1}{2}$ inches in height that have no transverse bond to the adjoining layers. It fulfils the requirements, however, if every joint throughout the body of the wall is well filled with good mortar and the vertical joints are well rammed with the edge of the trowel. The New York building laws require that every sixth course shall be a header course; that is, that five courses of stretchers must come between two courses

of headers. For factory and warehouse purposes, where the walls have to sustain heavy weights, it is better to have every fourth course a header course, thus giving three courses of stretchers between the header courses.

The wall is not so liable to split in its thickness, however, as it is to crack longitudinally, as would be shown by a crack up and down the face. In such a case, the garden bond is really stronger than either the English or the Flemish

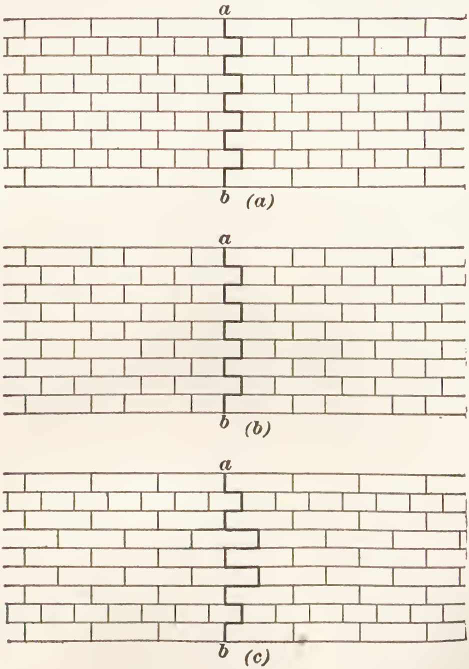


Fig. 6

bond. Of course, if the wall cracks exactly vertically the brick will be broken and in any bond the same number of brick will crack. Usually, however, a crack in brickwork follows the mortar joints, as shown in Fig. 6, in which view (*a*) represents English bond; (*b*), Flemish bond; and (*c*), garden bond. Nine courses of brickwork are considered in each example, and in each case the probable path of the

crack is indicated by the line *a b*. As can be seen from the illustration, the total length of vertical crack in each case is the same. However, the length of the line of fracture, or the contact area, will be found greater in the garden bond than in either the English or the Flemish bond, because the lap of the brick is greater.

11. Bonding of Face Brick.—When either face or pressed brick are used for the exterior facing of a wall, it detracts from the uniform appearance of the brickwork if the bonding headers appear on the exterior face of the wall. This difficulty can be avoided either by cutting the face brick and the rough brick or by using steel-wire ties to bond

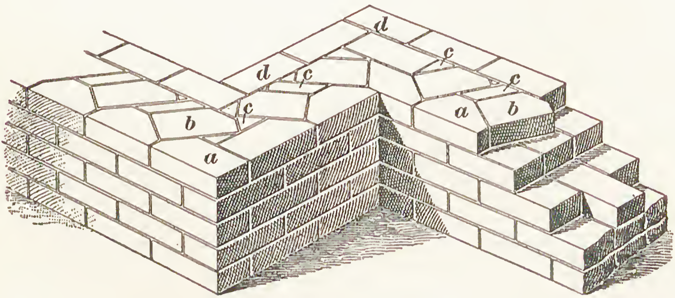


FIG. 7

the brick together. If no tie or bond is used, the whole 4 inches of brickwork on the face of the wall will have no other connections with the rest of the brick than that given by the adhesion of the mortar, and might be pushed away bodily from the rough brick.

12. In Fig. 7 is shown a 12-inch wall with the face brick bonded to the common brick by what is known as **diagonal,** or **herring-bone, bond.** At *a* is shown the front brick cut at the angles; at *b*, the bonding brick laid diagonally; at *c*, the different-shaped bats laid to form the closers of the bond brick; and at *d*, the inside course of stretchers. It is customary to lay an inside course of headers immediately over the course shown in the figure.

The New York building laws require that "where walls are faced with brick in running bond, every sixth course shall be bonded into the backing by cutting the corners of

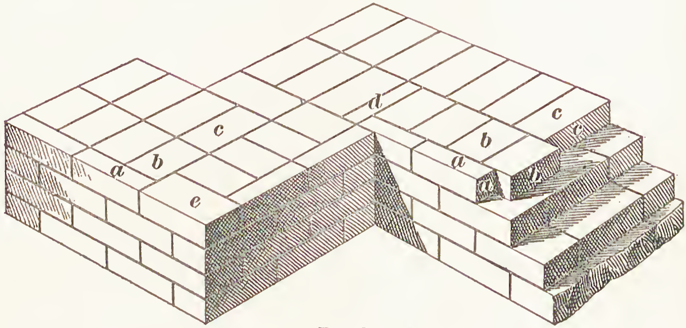


Fig. 8

the face brick and putting in diagonal headers behind, or by splitting the face brick in half and backing the same with a continuous row of headers."

The second method just mentioned is illustrated in Fig. 8. The face brick cut lengthwise are shown at *a*, and the three-quarter bats bonding in back of the face brick are shown at *b*. The whole brick *c* bond on the inside of the wall, and the closer *d* closes up the angle. The whole face brick on the corner of the wall is shown at *e*.

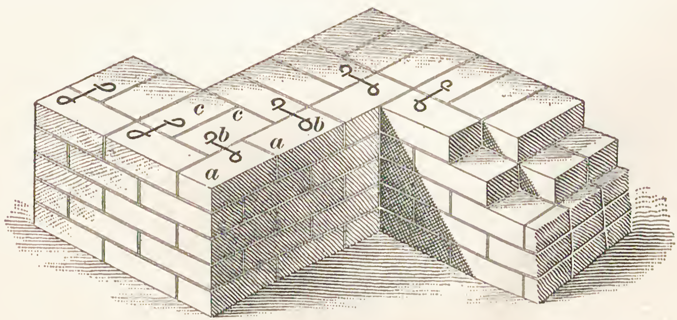


Fig. 9

13. In Fig. 9 is shown one method of bonding face brick with **metal ties.** The ties, or bonders, *b* are made either of steel or of galvanized-iron wire and are twisted at the

ends, as shown. They are laid in every sixth course of brick and are placed so as to hold together the outside course *a* and the inside course *c*. The principal objection to the use of steel or iron bonders is the danger of rust, although by the time their efficiency has been destroyed by the action of rust, the mortar used should have hardened sufficiently to keep the face brick in place.

A better method of tying front brick to the common brick in the back of the wall is to use perforated steel ties that are from $\frac{3}{32}$ to $\frac{1}{8}$ inch thick and have about half the metal punched out. The brick may be brought down to a very close joint, and the clinching spaces make a very firm and satisfactory

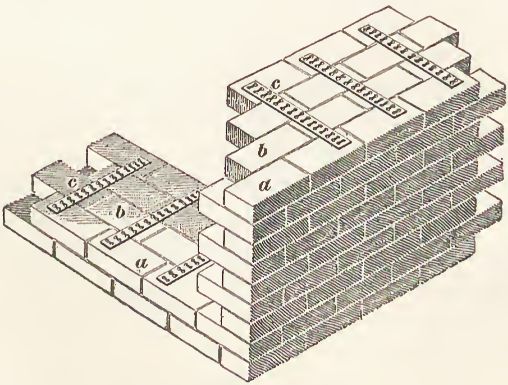


Fig. 10

binder. Fig. 10 shows the application of these bonding strips. Here the pressed-brick facing is shown at *a*, the common brick in the back of the wall at *b*, and the perforated steel ties that bond the pressed brick to the common brick at *c*.

14. Bonding of Hollow Walls.—While hollow walls are more expensive to build than solid walls, they are sometimes used, particularly for dwellings. They are superior to solid walls in that moisture cannot penetrate them; also, since the intervening space acts as an insulating medium, a house built of hollow walls is cooler in summer and warmer in winter than one built of solid walls.

In the ideal hollow wall, the air space is uninterrupted, having no braces connecting the inner and outer parts. Of course, in practice, it is necessary to have some bonding

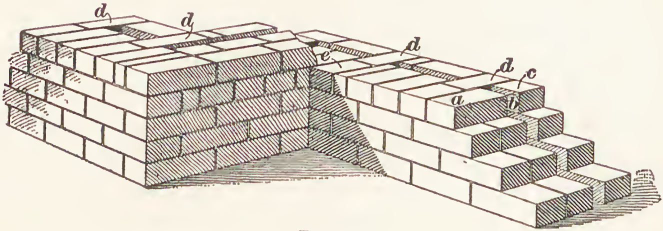


FIG. 11

between the two parts, but the style of bonding should be carefully considered. By permitting the passage of moisture through the wall where it is bonded, brick bonding neutralizes some of the benefit derived by making the walls hollow. To provide a continuous air space when a wall is penetrated by openings is practically impossible, though it may be closely approximated.

15. Fig. 11 shows one form of hollow wall with an 8-inch outer wall *a*, a 2-inch air space *b*, and a 4-inch inner wall *c*. Except at the corners, this wall is bonded every sixth course in height and every 12 inches in length, as shown at *d*. The header brick *e* that join the bond *d* are three-quarter bats, and the bond brick have a bearing of 2 inches on the front wall.

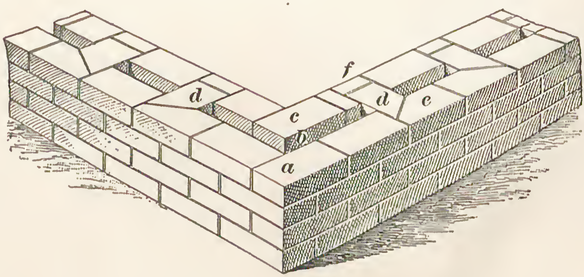


FIG. 12

Fig. 12 shows a 10-inch wall that has a 4-inch outer wall *a*, a 2-inch air space *b*, and a 4-inch inner wall *c*. The bond brick are cut at an angle, as shown at *d*, and where they miter

in the front wall, the front brick are also cut, as at *e*. The 2-inch spaces left in the rear wall *c* where the bond brick occur are filled with quarter-bat closers, as shown at *f*.

16. Probably the best way of bonding the two sides of a hollow wall is to use metal ties, as they will not carry any moisture across, especially when there is a dip or sudden bend in their length. This method of bonding a double wall is illustrated in Fig. 13. At *a* is shown the outer 4-inch wall; at *b*, the air space; at *c*, the inner 4-inch wall; and at *d*, the metal ties. These ties are called *Morse patent ties*.

At (*e*), (*f*), and (*g*) are shown other forms of ties. The form shown at (*g*) is probably the best, provided the walls

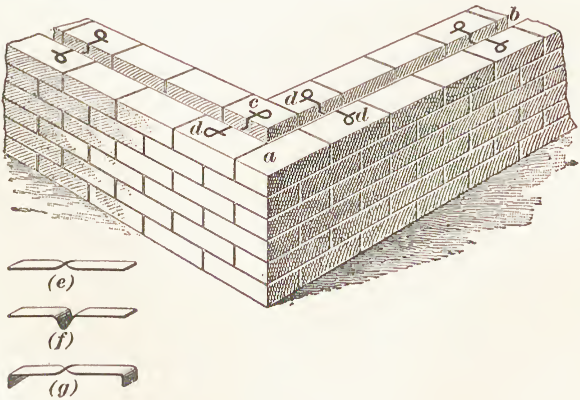


FIG. 13

are more than one brick thick so that the turned-up ends of the tie will not show. When any of the metal ties *d*, (*e*), or (*f*) are used, they should be spaced every 24 inches in every fourth course. Since the form of tie shown at (*g*) is stronger, it need be used only in every eighth course. All metal ties should be dipped in hot pitch to prevent them from rusting.

17. Bonding of Walls at Angles. — In building brick walls, it is necessary that the angles in the walls be properly bonded. When the two walls forming the angle are carried up at the same time, the bonding at the corners is easily effected; if, however, one wall is built a few weeks

ahead of the other, owing to a delay in getting materials required for it, particular care must be taken that the two parts will bond together properly.

In such cases, the wall first built is generally left toothed, as shown in Fig. 14. In order to unite the two walls more firmly, anchors made of $\frac{3}{8}'' \times 2''$ wrought iron, with one end turned up 2 inches, as at *a*, and the other bent around a $\frac{5}{8}$-inch bar, should be built into the side wall about every 4 feet in height, as shown at *b*. These anchors should be long enough to extend at least 12 inches, or the depth of one and one-half brick laid the long way, into the side wall, and the center of the $\frac{5}{8}$-inch bar should be about 8 inches from the back of the front wall.

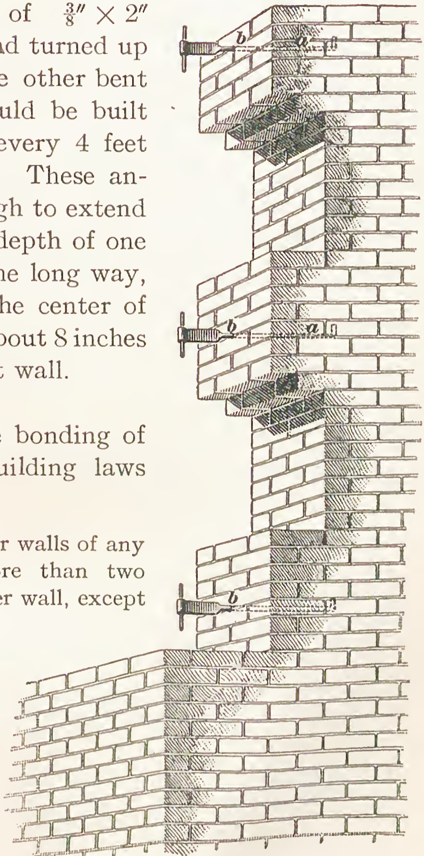


Fig. 14

18. In regard to the bonding of angles, the New York building laws are as follows:

In no case shall any wall or walls of any building be carried up more than two stories in advance of any other wall, except by permission of the Commissioner of Buildings having jurisdiction, but this prohibition shall not include the enclosure walls for skeleton buildings. The front, rear, side, and party walls shall be properly bonded together, or anchored to each other every six (6) feet in their height by wrought-iron tie-anchors, not less than one and one-half ($1\frac{1}{2}$) inches by three-eighths ($\frac{3}{8}$) of an inch in size, and not less than twenty-four (24) inches in length. The side anchors shall be built into the side or party walls not less than sixteen (16) inches, and into the front and rear walls, so as to secure the front and rear walls to the side, or party, walls when not built and bonded together.

DIFFICULTIES IN BRICKLAYING

19. Joining New Walls to Old Walls.—In joining a new wall to one that has been built for some time, especially if the walls come at right angles, the new work should not be toothed, or bonded, into the old work unless the new work is laid up in cement mortar. All masonwork built with lime mortar will settle somewhat, owing to a slight compresion of the mortar joints, and this settlement is liable to cause a crack where old and new work is bonded together. In place of toothing, if lime mortar is to be used, a groove usually the width of a brick should be cut perpendicularly in the old wall, so as to make what is known as a *slip joint.*

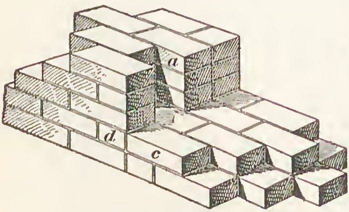


FIG. 15

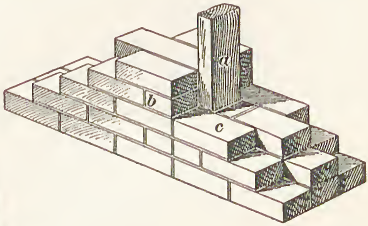


FIG. 16

The method of bonding just described is shown in Fig. 15. At *a* is shown the groove, or chase, cut where the new wall is to enter in the old wall, while at *c* is shown the new wall and *d*, the old wall.

In cheap construction, where new work is bonded into old, the method most commonly used is to nail a piece of 2″ × 4″ timber against the wall, as in Fig. 16, where *a* shows the 2″ × 4″ timber spiked to the old wall *b* and entering the center of the new wall *c*.

20. Laying Brick in Severe Weather.—When brick are dry, they absorb moisture from the mortar in which they are laid and thus prevent the mortar from attaining its customary strength. It is therefore very important, especially in warm weather, that all brick be wetted with water before they are laid in the wall.

As explained in *Sands and Cements*, neither lime nor cement mortar will set well in freezing weather. In New York City, there is a law against laying brick during freezing temperatures, but the law is not enforced; consequently, in laying brick, it seems to make very little difference to the contractor or architect whether it is summer or winter—the work goes on just the same. On account of this disregard for the laws, many buildings erected during freezing weather either collapse or become weakened as soon as the weather gets warm. On the first warm spring day in 1905, in New York City, six large buildings of the "flat-house" type under construction fell in for no other reason than that just stated. These buildings would probably never have collapsed had proper precautions been taken.

THICKNESS OF BRICK WALLS

21. Size of Brick and Mortar Joints.—There is no standard size of brick in America. The dimensions of brick vary with the locality and also with the maker. In the New England States, the average size of common brick is about $7\frac{3}{4}$ in. × $3\frac{3}{4}$ in. × $2\frac{1}{4}$ in.; and New York and New Jersey brick will run about 8 in. × 4 in. × $2\frac{1}{2}$ in. Walls laid in these brick will run normally 8, 12, 16, and 20 inches in thickness for 1, $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ brick. Most of the western common brick measure $8\frac{1}{2}$ in. × $4\frac{1}{8}$ in. × $2\frac{1}{2}$ in., and the thickness of the walls measures about 9, 13, 18, and 22 inches for 1, $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ brick. On the seacoast of some of the Southern States, the brick are made with a large percentage of sand, and will average 9 in. × $4\frac{1}{2}$ in. × 3 in.

Most manufacturers of pressed brick use molds of the same size; hence, pressed brick are more uniform in size. They are generally $8\frac{3}{8}$ in. × $4\frac{1}{8}$ in. × $2\frac{3}{8}$ in. Pressed brick are also made $1\frac{1}{2}$ inches thick. A form frequently used and known as Roman, or Pompeian, brick is 12 in. × 4 in. × $1\frac{1}{2}$ in. in size. In order that a good bond may be secured, brick should be made of such size that two headers and a joint will equal one stretcher

In ordinary brickwork, the joints should not average more than $\frac{1}{4}$ inch in thickness. In pressed brickwork, however, the joints may be made smaller, probably $\frac{1}{8}$ to $\frac{3}{16}$ inch, because the brick are smoother and have no irregular projections.

22. Laws Governing Thickness of Walls.—In order that the design and construction of walls for buildings of various dimensions used for dwellings, warehouses, and other purposes may be carried out intelligently, a knowledge of the thickness of walls required is very important. With this object in mind, an extract is given from the building laws of New York City that relate to the thickness of brick walls in proportion to their height. The laws of other cities do not differ very materially from the New York laws, and these may therefore be safely taken as a standard.

WALLS FOR DWELLING HOUSES

The expression "walls for dwelling houses" shall be taken to mean and include in this class walls for the following buildings: Dwellings, asylums, apartment houses, convents, club houses, dormitories, hospitals, hotels, lodging houses, tenements, parish buildings, schools, laboratories, studios.

1. The walls above the basement of dwelling houses not over three stories and basement in height, nor more than 40 feet in height, and not over 20 feet in width, and not over 55 feet in depth, shall have side and party walls not less than 8 inches thick [see Fig. 17 (*a*)], and front and rear walls not less than 12 inches thick.

2. All walls of dwellings exceeding 20 feet in width and not exceeding 40 feet in height, shall be not less than 12 inches thick [see Fig. 17 (*b*)].

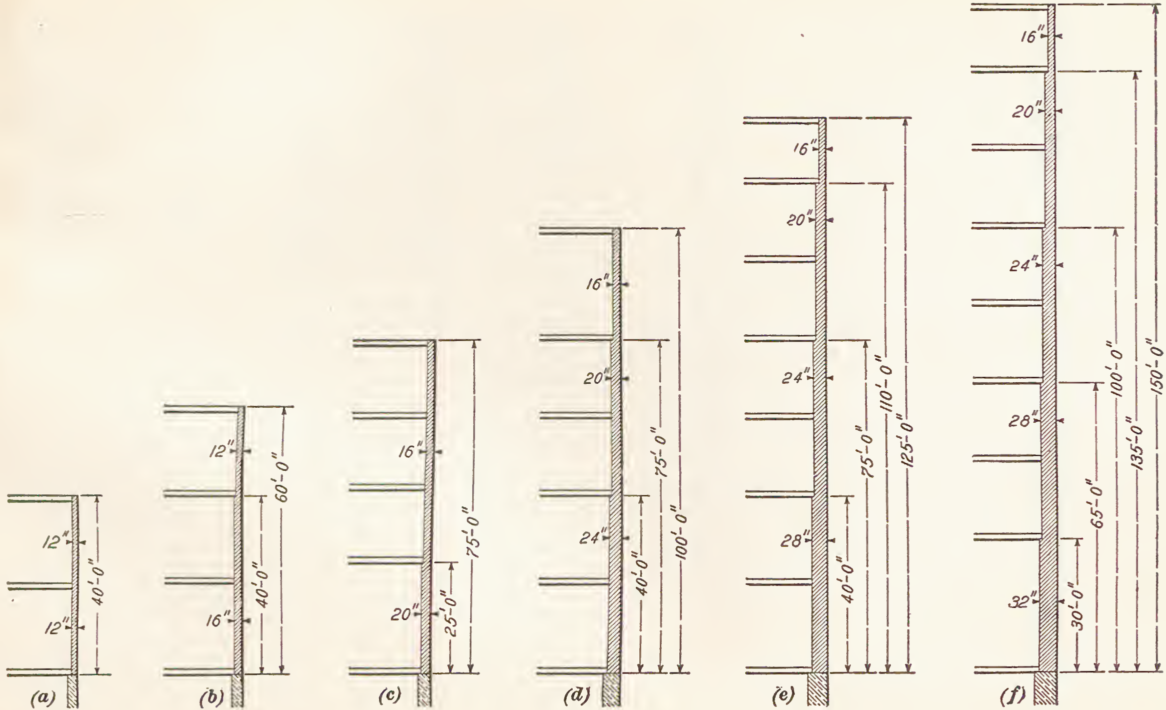
3. All walls of dwellings 26 feet or less in width between bearing walls which are hereafter erected or which may be altered to be used for dwellings and being over 40 feet in height and not over 50 feet in height, shall be not less than 12 inches thick above the foundation walls [see Fig. 17 (*c*)].

No wall shall be built having a 12-inch-thick portion measuring vertically more than 50 feet.

4. If over 50 feet in height and not over 60 feet in height, the walls shall be not less than 16 inches thick in the story next above the foundation walls and from thence not less than 12 inches to the top [see Fig. 17 (*d*)].


8"
8"
40'-0"
(a)
12"
12"
40'-0"
(b)
12"
12"
50'-0"
(c)
12"
16"
60'-0"
(d)
12"
12"
16"
25'-0"
75'-0"
(e)
12"
16"
16"
20"
40'-0"
75'-0"
100'-0"
(f)
12"
16"
20"
24"
40'-0"
75'-0"
110'-0"
125'-0"
(g)
12"
16"
20"
24"
28"
30'-0"
65'-0'
100'-0"
135'-0"
150'-0"
(h)

FIG. 17


(a)
(b)
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12"
16"
20"
24"
28"
32"
40'-0"
60'-0"
25'-0"
75'-0"
100'-0"
110'-0"
125'-0"
30'-0"
65'-0"
135'-0"
150'-0"

FIG. 18

5. If over 60 feet in height, and not over 75 feet in height, the walls shall be not less than 16 inches thick above the foundation walls to the height of 25 feet, or to the nearest tier of beams to that height, and from thence not less than 12 inches thick to the top [see Fig. 17 (*e*)].

6. If over 75 feet in height, and not over 100 feet in height, the walls shall be not less than 20 inches thick above the foundation walls to the height of 40 feet or to the nearest tier of beams to that height, thence not less than 16 inches thick to the height of 75 feet, or to the nearest tier of beams to that height, and thence not less than 12 inches thick to the top [see Fig. 17 (*f*)].

7. If over 100 feet in height, and not over 125 feet in height, the walls shall be not less than 24 inches thick above the foundation walls to the height of 40 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 75 feet, or to the nearest tier of beams to that height; thence not less than 16 inches thick to the height of 110 feet, or to the nearest tier of beams to that height; and thence not less than 12 inches thick to the top [see Fig. 17 (*g*)].

8. If over 125 feet in height and not over 150 feet in height, the walls shall be not less than 28 inches thick above the foundation walls to the height of 30 feet, or to the nearest tier of beams to that height; thence not less than 24 inches thick to the height of 65 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 100 feet, or to the nearest tier of beams to that height; thence not less than 16 inches thick to the height of 135 feet, or to the nearest tier of beams to that height; and thence not less than 12 inches thick to the top [see Fig. 17 (*h*)].

9. If over 150 feet in height, each additional 30 feet in height or part thereof, next above the foundation walls, shall be increased 4 inches in thickness, the upper 150 feet of wall remaining the same as specified for a wall of that height.

WALLS FOR WAREHOUSES

The expression "walls for warehouses" shall be taken to mean and include in this class walls for the following buildings: Warehouses, stores, factories, mills, printing houses, pumping stations, refrigerating houses, slaughter houses, wheelwright shops, cooperage shops, breweries, light and power houses, sugar refineries, office buildings, stables, markets, railroad buildings, jails, police stations, court houses, observatories, foundries, machine shops, public assembly buildings, armories, churches, theaters, libraries, museums.

1. The walls for all warehouses, 25 feet or less in width between walls or bearings, shall be not less than 12 inches thick to the height of 40 feet above the foundation walls [see Fig. 18 (*a*)].

2. If over 40 feet in height, and not over 60 feet in height, the walls shall be not less than 16 inches thick above the foundation walls to the height of 40 feet, or to the nearest tier of beams to that height, and thence not less than 12 inches thick to the top [see Fig. 18 (*b*)].

3. If over 60 feet in height, and not over 75 feet in height, the walls shall be not less than 20 inches thick above the foundation walls to the height of 25 feet, or to the nearest tier of beams to that height, and thence not less than 16 inches thick to the top [see Fig. 18 (*c*)].

4. If over 75 feet in height, and not over 100 feet in height, the walls shall be not less than 24 inches thick above the foundation walls to the height of 40 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 75 feet, or to the nearest tier of beams to that height; and thence not less than 16 inches thick to the top [see Fig. 18 (*d*)].

5. If over 100 feet in height, and not over 125 feet in height, the walls shall be not less than 28 inches thick above the foundation walls to the height of 40 feet, or to the nearest tier of beams to that height; thence not less than 24 inches thick to the height of 75 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 110 feet, or to the nearest tier of beams to that height; and thence not less than 16 inches thick to the top [see Fig. 18 (*e*)].

6. If over 125 feet in height, and not over 150 feet, the walls shall be not less than 32 inches thick above the foundation walls to the height of 30 feet, or to the nearest tier of beams to that height; thence not less than 28 inches thick to the height of 65 feet, or to the nearest tier of beams to that height; thence not less than 24 inches thick to the height of 100 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 135 feet or to the nearest tier of beams to that height; and thence not less than 16 inches to the top [see Fig. 18 (*f*)].

7. If over 150 feet in height, each additional 25 feet in height, or part thereof next above the foundation walls shall be increased 4 inches in thickness, the upper 150 feet of wall remaining the same as specified for a wall of that height.

23. Thickness of Walls in Different Cities. Although alike in the main, the building laws of the several cities differ from one another in many points, particularly in the methods of measuring the thickness of walls. For this reason, Tables I, II, and III have been compiled, the first two giving the thickness of warehouse walls and the third the thickness of walls for residences. Some cities, as, for instance, New York and Boston, give the height of walls

in feet; others, notably New Orleans and Denver, measure the heights in stories; while still others, as Washington and Cleveland, specify that a certain thickness of wall shall extend to a certain story, but state that this story must not be more than a given number of feet from the foundation. Therefore, in preparing the tables, several heights of stories were selected, so that all the laws could be made to apply to the same case. In every instance where the law required that the walls be thicker as the building is made wider, the minimum width was used; as in New York, 25-foot span for warehouses, and in Philadelphia, 26-foot span. It will be noticed in Tables I and II that dimensions for very high buildings are not given for some cities. This is because the height of buildings in many cases is limited in those localities. In Denver, a building cannot be over 125 feet in height, and in Washington, the government has limited the height to 130 feet.

The thickness of the walls in nearly all the cities is given in inches. In Cleveland, however, the law gives the thickness of the wall in the number of brick, but the size of the brick and the thickness of the mortar joints are also specified, so that the figures can easily be reduced to inches. In Washington, the thickness of walls of residences is specified, and a note states that $4\frac{1}{2}$ inches must be added to this thickness for warehouse walls. In Tables I and II, however, 5 inches instead of $4\frac{1}{2}$ inches is added, so as to eliminate all fractions. It will be noted that some laws call a wall that is evidently a brick and one-half thick 12 inches, while others call it 13 inches. This is due to different customs in different cities and the different sizes of brick used. As the laws governing the thickness of foundations differ greatly according to the locality, they cannot be given here; however, they may be found in the ordinances of the city or town in which the building is to be erected and are usually from 4 to 8 inches thicker than the wall directly above them. In some of the cities, as, for instance, Philadelphia, Boston, and New Orleans, walls of the same thickness are used for both warehouses and residences Tables I, II, and III apply to brick walls only.

TABLE 1—THICKNESS OF BRICK WALLS FOR WAREHOUSES UP TO SEVEN STORIES IN HEIGHT

Name of City	Number of Stories and Height of Building	Story and Height of Each						
		First 19′	Second 13′ 4″	Third 13′ 4″	Fourth 13′ 4″	Fifth 13′ 4″	Sixth 13′ 4″	Seventh 13′ 4″
		Thickness of Brick Wall, in Inches						
Washington	Two stories 32 feet 4 inches	14	14					
St. Louis		18	13					
Denver		13	13					
Memphis		13	13					
Boston		16	12					
New York		12	12					
Philadelphia		18	13					
Chicago		12	12					
Minneapolis		12	12					
New Orleans		13	13					
Cleveland		13	13					
San Francisco		17	13					
Washington	Three stories 45 feet 8 inches	23	18	18				
St. Louis		18	18	13				
Denver		17	17	13				
Memphis		17	17	13				
Boston		20	16	16				
New York		16	16	12				
Philadelphia		22	13	13				
Chicago		16	12	12				
Minneapolis		16	12	12				
New Orleans		13	13	13				
Cleveland		17	13	13				
San Francisco		17	17	13				
Washington	Four stories 59 feet	23	18	18	18			
St. Louis		22	18	18	13			
Denver		21	17	17	13			
Memphis		21	17	17	13			
Boston		20	16	16	16			
New York		16	16	16	12			
Philadelphia		22	18	13	13			
Chicago		20	16	16	12			
Minneapolis		16	16	12	12			
New Orleans		18	18	13	13			
Cleveland		17	17	13	13			
San Francisco		17	17	17	13			

TABLE I—(*Continued*)

Name of City	Number of Stories and Height of Building	Story and Height of Each — First 19′	Second 13′ 4″	Third 13′ 4″	Fourth 13′ 4″	Fifth 13′ 4″	Sixth 13′ 4″	Seventh 13′ 4″
		Thickness of Brick Wall, in Inches						
Washington ...	Five stories 72 feet 4 inches	27	23	23	23	18		
St. Louis......		22	22	18	18	13		
Denver........		21	21	17	17	13		
Memphis......		21	21	17	17	17		
Boston........		20	20	20	20	16		
New York.....		20	16	16	16	16		
Philadelphia...		26	18	18	13	13		
Chicago.......		20	20	16	16	16		
Minneapolis ...		20	16	16	12	12		
New Orleans...		18	18	18	13	13		
Cleveland		17	17	17	13	13		
San Francisco .		21	17	17	17	13		
Washington ...	Six stories 85 feet 8 inches	31	27	23	23	23	18	
St. Louis......		26	22	22	18	18	13	
Denver........		26	21	21	17	17	13	
Memphis......		25	21	21	17	17	17	
Boston........		24	20	20	20	20	16	
New York.....		24	24	24	20	20	16	
Philadelphia...		26	22	18	18	13	13	
Chicago.......		20	20	20	16	16	16	
Minneapolis ...		20	20	16	16	16	12	
New Orleans...		22	18	18	18	13	13	
Cleveland		22	17	17	17	13	13	
San Francisco .		21	21	17	17	17	13	
Washington ...	Seven stories 99 feet	31	27	27	23	23	23	18
St. Louis......		26	26	22	22	18	18	13
Denver........		26	21	21	21	17	17	17
Memphis......		25	21	21	21	17	17	17
Boston........		24	20	20	20	20	20	16
New York.....		24	24	24	20	20	16	16
Philadelphia...		30	22	22	18	18	13	13
Chicago.......		20	20	20	20	16	16	16
Minneapolis ...		20	20	20	16	16	16	12
New Orleans...		22	22	18	18	18	13	13
Cleveland		22	22	17	17	17	13	13

TABLE II

THICKNESS OF BRICK WALLS FOR WAREHOUSES FROM EIGHT TO TWELVE STORIES IN HEIGHT

Name of City	Number of Stories and Height of Building	Story and Height of Each											
		First 19′	Second 13′ 4″	Third 13′ 4″	Fourth 13′ 4″	Fifth 13′ 4″	Sixth 13′ 4″	Seventh 13′ 4″	Eighth 13′ 4″	Ninth 13′ 4″	Tenth 13′ 4″	Eleventh 13′ 4″	Twelfth 13′ 4″
		Thickness of Brick Wall, in Inches											
Washington......	Eight stories 112 feet 4 inches	39	35	35	31	27	27	23	23				
St. Louis.........		30	26	26	22	22	18	18	13				
Denver..........		30	26	21	21	21	17	17	17				
Memphis.........		29	25	21	21	21	17	17	17				
Boston..........		28	24	20	20	20	20	20	16				
New York.......		28	28	28	24	24	20	20	20				
Philadelphia		30	26	22	22	18	18	13	13				
Chicago..........		24	24	20	20	20	16	16	16				
Minneapolis......		24	20	20	20	16	16	16	12				
New Orleans.....		22	22	22	18	18	18	13	13				
Cleveland........		22	22	22	17	17	17	13	13				

Washington......		39	35	35	31	27	27	23	23	23			
St. Louis.........		30	30	26	26	22	22	18	18	13			
Memphis.........		29	25	25	21	21	21	17	17	17			
Boston..........	Nine stories	28	28	24	20	20	20	20	20	16			
New York.......	125 feet 8 inches	32	32	28	28	24	24	24	20	20			
Philadelphia		34	26	26	22	22	18	18	13	13			
Chicago..........		24	24	24	20	20	20	16	16	16			
Minneapolis......		24	24	20	20	20	16	16	16	- 12			
Cleveland........		26	22	22	22	17	17	17	13	13			
St. Louis.........		34	30	30	26	26	22	22	18	18	13		
Memphis.........		29	29	25	25	21	21	21	17	17	17		
Boston..........		32	28	28	24	20	20	20	20	20	16		
New York.......	Ten stories	32	32	28	28	24	24	24	20	20	20		
Philadelphia	139 feet	34	30	26	26	22	22	18	18	13	13		
Chicago..........		28	28	24	24	24	20	20	20	16	16		
Minneapolis......		24	24	24	20	20	20	16	16	16	12		
Cleveland........		26	26	22	22	22	17	17	17	13	13		

TABLE II—(*Continued*)

Name of City	Number of Stories and Height of Building	Story and Height of Each: First 19′	Second 13′ 4″	Third 13′ 4″	Fourth 13′ 4″	Fifth 13′ 4″	Sixth 13′ 4″	Seventh 13′ 4″	Eighth 13′ 4″	Ninth 13′ 4″	Tenth 13′ 4″	Eleventh 13′ 4″	Twelfth 13′ 4″
		Thickness of Brick Wall, in Inches											
St. Louis.........	Eleven stories 152 feet 4 inches	34	34	30	30	26	26	22	22	18	18	13	
Memphis.........		29	29	25	25	25	21	21	17	17	17	17	
Boston..........		32	32	28	28	24	20	20	20	20	20	16	
New York.......		36	32	28	28	28	24	24	20	20	20	16	
Philadelphia		38	30	30	26	26	22	22	18	18	13	13	
Chicago..........		28	28	24	24	24	20	20	20	16	16	16	
Cleveland........		31	26	26	22	22	22	17	17	17	13	13	
St. Louis.........	Twelve stories 165 feet 8 inches	34	34	34	30	30	26	26	22	22	18	18	13
Memphis.........		29	29	29	25	25	25	21	21	21	17	17	17
Boston..........		36	32	32	28	28	24	20	20	20	20	20	16
New York.......		36	32	32	28	28	28	24	24	20	20	20	16
Philadelphia		38	34	30	30	26	26	22	22	18	18	13	13
Chicago..........		28	28	28	24	24	24	20	20	20	16	16	16
Cleveland........		31	31	26	26	22	22	22	17	17	17	13	13

TABLE III

THICKNESS OF BRICK WALLS FOR DWELLING HOUSES

Name of City	Number of Stories and Height of Building	First 12′	Second 11′	Third 10′ 6″	Fourth 10′	Fifth 10′	Sixth 10′	Seventh 10′
		Thickness of Brick Wall, in Inches						
New York .	Two stories 23 feet	12	12					
Denver		13	13					
Washington		9	9					
Cleveland . .		13	13					
Chicago		12	8					
Memphis . . .		13	13					
New York .	Three stories 33 feet 6 inches	12	12	12				
Denver		17	13	13				
Washington		9	9	9				
Cleveland . .		13	13	13				
Chicago		12	12	8				
Memphis . . .		13	13	13				
New York .	Four stories 43 feet 6 inches	12	12	12	12			
Denver		17	17	13	13			
Washington		13	13	13	13			
Cleveland . .		18	13	13	13			
Chicago		16	16	12	12			
Memphis . .		13	13	13	13			
New York	Five stories 53 feet 6 inches	16	12	12	12	12		
Denver		21	21	17	17	13		
Washington		18	13	13	13	13		
Cleveland . .		18	18	13	13	13		
Chicago . . .		16	16	16	12	12		
Memphis . .		17	13	13	13	13		
New York	Six stories 63 feet 6 inches	16	16	12	12	12	12	
Denver		26	21	21	17	17	13	
Washington		22	18	18	13	13	13	
Cleveland .		18	18	18	13	13	13	
Chicago . . .		20	16	16	16	12	12	
Memphis . .		17	17	13	13	13	13	
New York	Seven stories 73 feet 6 inches	16	16	12	12	12	12	12
Denver . . .		26	21	21	21	17	17	17
Washington		22	18	18	18	13	13	13
Cleveland .		18	18	18	18	13	13	13
Chicago . . .		24	20	20	16	16	12	12
Memphis . .		17	17	17	13	13	13	13

TYPES OF BRICK WALLS

24. Solid Walls.—The solid brick walls of a building are not waterproof. A driving rainstorm of several days' duration will sometimes penetrate even a 2-foot wall and by wetting the inside surfaces, spoil whatever interior coverings the wall may have.

A house built of solid walls is likely to be cold in winter, warm in summer, and damp at all times. In solid brickwork, there is always a lack of insulation against heat and moisture.

Air is about the best, and certainly the cheapest, form of insulation. To obtain air insulation, several methods are resorted to. The one most in use consists in furring the inner surface of outside brick walls with furring strips and then fastening lath and plaster to these strips. The danger of fire spreading from floor to floor through the spaces between the furring strips, especially in hospitals, schoolhouses, and isolated private residences, has caused many excellent authorities to recommend the use of hollow brick walls in their stead.

25. Hollow Walls.—Hollow walls are intended to keep moisture from passing through, and, by providing an air space, keep the building much cooler in summer and warmer in winter. Constructive difficulties, however, largely offset their advantages, so that hollow walls are not often used in the United States. There is no doubt but that their use might be much extended with good results, more especially for isolated buildings. The objections to hollow walls are that more ground area is required and the cost of construction is greater.

26. Party Walls.—A **party wall** is a wall that separates two adjoining buildings and carries the floor and roof beams of both of them. A party wall is sometimes owned jointly by the two persons that own adjacent property. In such cases the center line of the party wall marks one of the boundary lines of the lot. The owner of one of two adjoining

lots has the right in most localities to build a party wall half way on the property on either side of the dividing line. In this case, the right to use the wall for floor and roof beams for another building may be purchased from the owner.

The floor loads on party walls are twice as great as the load on an outside wall; besides this, the necessity for thorough and complete fire protection is greater in party walls than in outside walls, because those on the outside can easily be reached in case of fire, while party walls, being enclosed by other walls, are more difficult of access. As building regulations differ materially in regard to the thickness of party walls, the best guide for determining their thickness is to make them 4 inches thicker in each story than the outside wall.

27. Curtain Walls.—In modern skeleton construction, the floor loads in a building are carried by the steel frame, and the walls called curtain walls carry no load other than their own weight. There are a few high buildings in which the walls extend down to the foundations, but because it is desired to make these walls thin on account of the space they occupy and the high price of real estate in the business sections of cities, curtain walls are generally supported on the steel frame of the building, usually at every floor. In this way much thinner walls can be used, and valuable space can be saved.

28. Some authorities call walls placed in between columns but resting on their own foundation and not supported by girders *curtain walls*, and walls supported at every story or every other story by girders, *enclosure walls;* however, most engineers class both styles as *curtain walls*. Walls resting entirely on their foundations and not supported by girders are not used much at present. If they are used, they should not be allowed to touch the metal columns, as their faster rate of settlement will be sure to cause unsightly cracks.

29. Following is an extract in regard to enclosure walls from the New York City building laws:

Walls of brick built in between iron or steel columns, and supported wholly or in part on iron or steel girders, shall be not less than 12 inches thick for 75 feet of the uppermost height thereof, or to the nearest tier of beams to that measurement, in any building so constructed, and every lower section of 60 feet, or to the nearest tier of beams to such vertical measurement, or part thereof, shall have a thickness of 4 inches more than is required for the section next above it down to the tier of beams nearest to the curb level.

AGREEMENTS AND SPECIFICATIONS

Serial 1900-2 — Edition 1

INTRODUCTION

CONTRACTS

CONTRACTS IN GENERAL

1. Nature of a Contract.—A contract is a formal act whereby two or more parties bind themselves mutually to do or not to do some definite thing. By entering into a contract each party conveys power over himself to another party in consideration of something to be done by the other. If, for any reason, one of the parties to a contract fails in fulfilling the terms of the contract, the injured party has recourse to the courts of justice, or arbitration if legally provided, for such relief as the law or arbitration affords. It is thus an important feature of a properly drawn contract that all its provisions shall be *legally enforcible.*

2. Essentials of a Contract.—A contract is legally enforcible only when it fulfils certain conditions. The following four conditions are essential to all contracts: (1) The parties to the contract must be legally able to contract; (2) there must be an exchange of something of value for its legal equivalent; (3) the purpose of the contract must be lawful; (4) there must be a mutual understanding between the contracting parties.

3. Contracting Parties.—The contracting parties may be divided into the following classes: (*a*) Private individuals; (*b*) corporations; (*c*) partnerships or unincorporated organizations, and (*d*) governmental departments. The ability of the contracting parties to enter into legally enforcible contracts is contingent upon certain qualifications described in the following:

(*a*) *Private Individuals.*—Private individuals, with some exceptions, are competent to enter into valid contracts. The contracts of infants (those under twenty-one years of age), imbeciles, inebriates, and lunatics are voidable. The power of married women to contract is regulated by statute in the various states.

Private individuals are often called upon to enter into contracts on behalf of other individuals, partnerships, corporations, and governments. An individual authorized to represent some one else is said to be an *agent*. The powers of an agent do not extend beyond the authority conferred upon him by his principal. An agent overstepping his authority not only cannot legally bind his principal, but may make himself liable for the fulfilment of the contract. As long as an agent acts within the scope of authority conferred upon him by the principal, or upon the authority of precedent, the principal remains responsible for the consequences of any act of the agent.

(*b*) *Corporations.*—A corporation is an organization whose legal existence is based upon a charter issued to it by a state. The **charter** specifically circumscribes and limits the powers of the corporation so that no corporation can legally contract beyond the limits imposed by its charter. The charter and by-laws of a corporation, or resolutions of its board of directors, empower certain of its officers or agents to bind the corporation by contracts. The contracts are valid only when entered into and signed by a duly authorized officer or agent of the corporation. It is usually necessary that in addition to the proper signature, the seal of the corporation be attached to the contract, and that the seal be duly attested by the secretary of the corporation.

(*c*) *Partnerships or Unincorporated Organizations.*—Unincorporated organizations, such as voluntary associations, clubs, societies, and congregations, have usually no legal existence, and contracts made with them are therefore difficult to enforce by lawsuit. A special form of unincorporated organization having a certain legal standing is the so-called **partnership** whereby two or more private parties unite for business purposes. The relations between a partnership and a third party are dependent, *first,* upon the contract between the partners whereon the partnership is based, and, *second,* upon the representation made by any or all of the partners to third parties. Generally speaking, all partners are legally bound by the signature of any one partner unless otherwise stipulated in the partnership agreement. A contract made with a partnership is usually enforcible against all or any of the individual partners, whether the partnership agreement so provides or not.

(*d*) *Governmental Departments.*—Governmental departments are often parties to contracts. Such contracts must be signed by a duly and legally authorized officer or agent of the particular government department. A contract with the government—whether Federal, State, County, or City—is binding on the public, only when all legal formalities prescribed by law have been scrupulously complied with, such as public notice to bidders, acceptance of bids, authorization of the official or agent, and many other particulars too numerous to mention here. Contracting with the government is a specialty in both its legal and financial aspects and will not be explained in detail here. Suffice it to say that great care is necessary in entering into contracts with the public, since any irregularity in the awarding of the contract is fatal to the claims of the contractor, unless the department is only quasi-public. Contracts made with the United States Government differ from ordinary contracts in that they are not always enforcible in the law courts against the government, since suit cannot always be brought against the United States Government without its own consent, but in most contracts action may be had in the United States courts; the government always may sue the contractor for non-compliance with the terms of the contract.

4. Consideration.—It was stated in Art. **2**, as one of the essentials for making a contract legal, that there must be an exchange of something of value (not necessarily money) between the contracting parties. This valuable something is called the **consideration.** Theoretically, the consideration must be adequate, the trade must be fair; but in practice the courts will not consider as inadequate a consideration declared adequate by the parties to the contract, regardless of how disproportionate the consideration may be, provided, however, that there is found no fraudulent intent. Thus, if *A* undertakes to furnish concrete for $3.00 per cubic yard on *B*'s job, he cannot escape from his contract even though the concrete would cost him $12.00 per cubic yard; but if *B* had fraudulently induced *A* to enter into the contract by misrepresentation, the contract would not necessarily bind *A*, although it would probably bind *B*.

5. Lawful Purpose.—The third of the conditions essential to the legality of a contract is, according to Art. **2**, the lawful purpose of the contract. Almost any purpose is lawful, provided it is not immoral or otherwise contrary to law or to public policy. A clause whereby a party waives his right to appeal to the courts, unless carefully drawn, is usually not enforcible. For instance, a clause calling for compulsory arbitration, is a case in point; such clauses have been usually classed by the courts as opposed to public policy.

6. Mutual Understanding.—The fourth and last condition required to make a contract legal is the presence of a **mutual understanding** between the contracting parties. Such mutual understanding is absolutely necessary. For example, a contract may be entered into by *A*'s sending a certain written proposal to *B* and by *B*'s unqualified acceptance of the proposal; but if *B* accepts the proposal with a change or reservation, his acceptance is void and no contract exists, unless *A* accepts the change or reservation. Thus, if *A*'s proposal is to construct a certain building complete for a certain sum of money, *B*'s unconditional acceptance of this offer will constitute a contract, provided *A*'s offer is accepted by *B* within

reasonable time. But if *B* writes a letter to *A*, stating that he will accept the proposal on the additional condition that *A* complete the work within a certain stipulated time, the acceptance is not binding and *A* is released from his proposal, unless he accepts the change or reservation, because there was at no time a mutual understanding, no meeting of the minds of *A* and *B*.

7. Classification of Contracts.—Contracts may be (*a*) written, (*b*) oral, or (*c*) implied.

(*a*) *Written Contracts.*—A **written contract** is one that is either written or printed, and signed by the contracting parties, and often *sealed*. A **seal** is usually a piece of red paper affixed to the document with mucilage; the sealing of the contract is sometimes necessary, but often only a formality, considered making the contract a more sacred document than it would be otherwise.

(*b*) *Oral Contracts.*—An **oral contract** (also sometimes called a *parol* or a *verbal* contract) is one to which the parties concerned agree verbally. Unless witnesses be present when an oral contract is made, it is of course impossible for one party afterwards to prove the existence and scope of the contract against the denial of the other party. Even if witnesses are available their testimony is likely to be contradictory, confused, and unsatisfactory. Oral contracts should, therefore, *not* be relied on, where written contracts can be made.

(*c*) *Implied Contracts.*—An **implied contract** is one *understood* to exist although not based on either a written or an oral contract. Most contracts, whether written or oral, imply some obligations on the part of the contracting parties not specifically stated in the contract, so that contracts are often not stated in full but are in part implied. Contracts may be implied by *acts*. Thus, if a tenant continues to occupy premises after the expiration of the lease, there may be an implied contract between owner and tenant to continue the lease on the old terms, although the original lease did not in any way provide for the contingency named. Implied contracts often lead to misunderstanding and should be avoided as far as possible.

8. Difference Between Written and Oral Contracts. One important difference between the written contract and the oral contract is that *no testimony is admissible* in explanation of the terms of a written contract, where the written contract forms the basis for an action in court; whereas testimony is not only admissible but usually indispensable where an oral contract is involved. The reason for this is the rule of law that *all written documents must speak for themselves,* and that the interpretation of all written documents is the function of the court or the judge. Therefore, if a written contract exists between *A* and *B,* and suit is brought to enforce the contract, neither side can offer evidence to show that the contract has a larger or different meaning from what it shows on its face. By the signing of a particular written contract all previous verbal understandings as to this contract become null and void.

9. Statutes of Frauds and Limitations.—In the several states there are codes of special laws known as the *statutes of frauds* and *statutes of limitations.*

The **statutes of frauds** impose certain forms and conditions which must be observed in order to make contracts binding, and prohibit the use of the oral contract where the contract cannot be fulfilled within a certain time (usually one year from its date). Therefore, all contracts should be in writing, especially if intended to run, or likely to run, for more than one year.

The **statutes of limitations** impose certain time limits within which lawsuits must be brought in order to collect a debt or enforce a claim. If no suit is brought within the time limit prescribed by law the claim or debt becomes null and void, and is said to be *outlawed.*

10. Contracts With Foreign Corporations.—In some of the states a so-called *foreign corporation* is barred from suing on a contract unless it has complied with certain special regulations. The word **foreign,** as here used, denotes a corporation incorporated in another state. Thus, a foreign corporation can contract in the state of New York, but cannot bring suit for damage under the contract unless, before enter-

ing upon the contract, the corporation had obtained a license from the Secretary of State of New York, and has kept the license alive. The laws of different states differ in this as in many other respects, so that the laws of contracts and the laws of corporations contain many pitfalls for the unwary. Any one engaging in the contracting business should therefore have the constant advice of a competent lawyer skilled in building cases and contract law.

ENGINEERING CONTRACTS

11. Varieties of Contracts.—Even a small engineering job calls for numerous contracts. There is, first, the contract between the owner and the engineer, whereby the owner retains the engineer; second, the contract between owner and contractor, providing for the construction of the work; and third, the several contracts of the contractor on one side, with subcontractors and material men on the other side. On large jobs, the engineer may contract with other engineers or architects for their services. There may be land to be bought, damages to be liquidated, stock and bonds to be sold, money to be borrowed, insurance and surety to be provided for; all of which call for contracts to be entered into. On engineering work, all, or at least most, of these contracts influence the position and responsibility of the engineer, and some of them are customarily prepared by him. Although the young engineer would not be likely to, and should not if called upon, draft an important contract, he should nevertheless understand the principles upon which contracts are based, and he should especially familiarize himself with the particulars of the *building contract*, that is, the contract between owner and contractor, so as to be able to make suggestions.

12. Documents of Building Contract.—A contract to build must set forth all of the understanding between owner and the contractor; that is, it must specify in detail what each is to do and not to do. In drafting a building contract, the engineer must view the proposed construction under three separate aspects, namely, *legal, financial,* and *technical.* The

documents in which these three aspects are considered are three in number, and are, respectively, the *agreement,* the *specifications,* and the *plans.* Legally, it makes no difference in which of these any particular fact is stated, since the three documents are usually made equally binding; but as a matter of fact, an almost universally accepted custom has been developed whereby all legal matters are placed in the agreement. The specifications are divided into two parts of which one, commonly called the *general specifications,* contains all matters pertaining especially to finance and business, while the other, called the *detail* or *construction specifications,* together with the plans, constitutes the more technical part of the contract, and is concerned especially with methods of construction and qualities and quantities of the material to be furnished by the contractor.

13. Contract and Agreement Not Synonymous. Many dictionaries and law books define the term *contract* as an *agreement;* in law, as such, the two words are therefore often used synonymously. Until recent years this was also the custom among engineers, architects, and contractors, and even now the words *contract* and *agreement* are sometimes loosely used by builders to express one and the same thing. The better usage is, however, to give to the word **contract** the larger scope embracing, as already stated, the *entire understanding* between owner and contractor, including the specifications, and plans, reserving the word **agreement** to denominate that particular document in which the purely legal matters are stated, and this usage is the one followed in this Section.

14. Special Features of Engineering Contracts.—It has already been pointed out that while an ordinary contract is essentially an agreement, an engineering contract is more than an agreement in that it embraces also a multitude of technical matters enumerated in the plans and specifications. A further difference is that, owing to the great and obvious importance of the technical matters, these are usually under the jurisdiction of a technical expert—an engineer or architect, as the case may be—who is, in a certain measure, a third party to any

engineering contract, and his approval should be indorsed on all the documents and papers.

15. Position of the Engineer.—In the sense used in the specifications the word *engineer* refers to a technical expert engaged by the owner for the purpose of preparing plans and specifications, as well as for supervising the erection of the work. Although employed by the owner and especially charged with the supervision of the construction, the engineer is usually assumed to occupy a position between owner and contractor, to act in case of dispute as an arbitrator between their conflicting interests, and, in general, to favor no side to the detriment of the other. In many cases this dual capacity of the engineer brings him into trying positions; but while the system is thus theoretically objectionable, it has, however, in practice been found to give better satisfaction than where the engineer is altogether the agent of the owner and nothing more.

16. Powers and Duties of the Engineer.—The engineer derives all his power from the stipulations of the contract between owner and contractor, and he cannot make decisions contrary to the letter and spirit of the contract, and have them sustained in court. But even though limited by the contract, the powers of the engineer are usually very great; he is often "sole judge of the work, its quality and character," almost any question arising is "subject to the decision of the engineer," and sometimes "the decision of the engineer is final and binding upon all parties," to quote a common stipulation from engineering contracts. This wording is, however, unfortunate, and as far as possible the plans and specifications should be absolutely definite. It is also a common requirement that the work is "to be completed according to specifications and to the acceptance and satisfaction of the engineer."

Great as are the powers thus conferred, they do not confer power upon the engineer to the exclusion of the courts, and either owner or contractor can bring suit in the courts against the other if dissatisfied with the decision of the engineer. The court is not bound to accept the judgment of the engineer, but will usually do so if the decision of the engineer is based upon

honest investigation, equity, and sound reasoning. Thus, the court should never, and will seldom, uphold the decision of the engineer if he departs from equity or from the requirements of plans and specifications.

17. It is the engineer's first duty to follow the specifications literally, and he usually is given no power to accept anything deviating therefrom. Although it is frequently done in practice, the engineer has no right to permit such substitution as, for example, pit-run gravel in place of sand and crushed rock, if these be called for by the specifications. Neither should he allow the substitution of hot twisted bars for cold twisted ones; nor accept cement not tested if tests are prescribed in the specifications. In this respect it makes no difference whether or not the substitute is "as good" or even better than the materials originally specified, nor can the engineer change the specifications or permit deviation therefrom on the ground that he is their author. Once they are agreed to by owner and contractor, the engineer loses control over plans and specifications, and instead of controlling them he is himself controlled by them, and they can be changed only by written supplemental agreements. An obvious exception is the case where the contract expressly reserves the right for the engineer to make minor changes or to accept substitutes; but such an arrangement is fraught with dangers.

18. Assistant Engineers and Inspectors.—Whatever governs the position of the engineer will also govern the position of his duly authorized representatives or agents, such as assistant engineers and inspectors. These are bound as much as the engineer by the requirements of the contract and have no right to demand what is not in the contract nor to waive anything that is therein.

If an inspector is constantly present on the job, it becomes his duty to see that the specifications are lived up to. The continual presence of a lax inspector may have exactly the opposite effect of the one intended, because the owner (or his legal representative) cannot usually stand idly by without objecting to obvious violations of the contract, and then after-

wards claim damages for defective work. But if, on the other hand, the engineer is not continually present, and the contractor slights the work during the absence of the engineer, then the owner can recover the damages suffered if the defects are subsequently discovered. Therefore, whatever inspection is given should be as efficient as possible, especially where the engineer is the sole judge of quality and where his decisions are final and binding.

It often makes no difference in the court's decision whether in point of fact the engineer is mistaken in his judgment. If he honestly believes and has tried fully to assure himself that the materials or workmanship are defective, and therefore rejects them, the court will probably uphold his decision and the contractor will thus be unable to recover damages in court for the rejected materials and workmanship, even though it might afterwards turn out that the rejected materials conformed to the specifications.

If, however, the engineer's decisions are *not* final and binding, his acceptance of inferior workmanship or materials does not bind the owner nor exonerate the contractor, and the owner can recover damages in the courts.

19. Waived Clauses.—It might seem as if the strict insistence by the engineer upon the letter and spirit of a contract might often work hardship on the contractor. Engineers and owners have, therefore, sometimes been influenced by a contractor's complaining of hard luck into granting him certain indulgences and easements of his contractual obligations. This, however, is a very poor policy since if the owner (or his engineer acting for him) repeatedly permits deviations from any one clause, it may be found that he has tacitly **waived** his rights under that clause, which becomes null and void. It cannot again be enforced, and as a result the contractor's surety bond often becomes invalidated. The engineer, therefore, throughout the period of construction, should carefully guard against any act that might be construed as constituting a waiver of the contract as a whole or any part thereof.

Similarly, the contractor must constantly guard his rights

lest he unwittingly be drawn into a position where he has waived the contract or parts thereof. For example, the contract drawings for a dam may include a small scale elevation upon which is shown an apparently plain molded cornice, but at a later date the owner presents a larger scale drawing of the cornice showing it to consist of intricate carved stone work. If then the contractor silently proceeds to install this cornice, or if he makes but a mild protest against the imposition, he cannot later recover the additional expense due to the extra work on the cornice because he has waived his rights by acquiescing. Where, therefore, the owner attempts to impose new and stricter conditions upon the contractor, or insists upon additional or more difficult work than originally provided for without offering adequate compensation, the contractor is entirely justified in refusing, and usually suffers if he does not refuse, to proceed with the additional work or to accept the new conditions. If, in an extreme case, he should thereby be forced to quit the contract, he will still have recourse to the courts for damages for violation of the contract by the owner.

20. Lawsuits.—Although it has been repeatedly stated in the preceding pages that a contract is enforcible by suit in courts of law, and although specific instances have been given where a suit at law would likely prove successful, it is by no means the intention here to encourage dependence upon the courts of law except as a last resort, since in most cases the loss of time, of money, and of energy will amount to far more than can be recovered by a lawsuit. Lawsuits are proverbially profitable only to the lawyer. Besides, some slight oversight or misunderstanding may cause an unfavorable decision even in an apparently favorable case, as it is usually extremely difficult to get a judge or a jury to understand technical matters. The uncertainty of the outcome of lawsuits is well illustrated by the fact that many decisions in cases involving matters pertaining to engineering, building, patents, and so forth, are reversed upon appeal to a higher court.

If, then, it is advisable to appeal to the courts only as a last resort, it becomes necessary to provide other means of adjust-

ing disputes, and the means usually adopted is *arbitration.* Arbitration, like action in court, is, however, not without disadvantages of its own, and the engineer should therefore use every legitimate means to bring about a compromise between the disputing parties before either of them resorts to law or to arbitration. There are certain owners, as there are certain contractors, who always have cases in litigation; but there is another and much larger group of both owners and contractors who take pride in the reputation of never having had a lawsuit, and who have profited largely thereby. The engineer who recognizes that engineering and construction are based upon legal principles, and yet succeeds in keeping his clients out of court and away from arbitration, will in the long run serve both his clients, his contractors, and himself to best advantage.

21. Arbitration.—As already stated, the duty of deciding whether or not the workmanship and materials are satisfactory and in accordance with the plans and specifications usually rests upon the engineer. Either owner or contractor may become dissatisfied with the decisions rendered by the engineer. If the owner becomes dissatisfied with the engineer's decisions, he can, of course, discharge the engineer, although it is believed that such a remedy is usually a mistake and should seldom be adopted. The contractor, if dissatisfied, has no such remedy, unless he can induce the owner to discharge a manifestly unjust engineer. In order to afford owner and contractor—and more especially the contractor—relief in such cases, a clause is often inserted in the specifications calling for arbitration by a semi-public board of arbitration, of which the Board of the New York Chamber of Commerce is the most notable example. Or, the arbitration may be performed by a board named in the contract or by a board composed usually of three men to be selected. Of these men, one is usually appointed or selected by the owner, one by the contractor, and the third, who becomes the chairman is selected and agreed upon by the two first chosen. Since the two first chosen may fail to agree in their choice

of the third member, provisions should be made in such emergency for the appointment of the third member by some entirely disinterested person such as, for instance, a judge of the court, the mayor, or some other government officer.

22. Arbitration by three men is usually very expensive since the arbitration takes much time, and the time of the class of men that usually are and should be chosen as arbitrators is valuable. For this reason, **arbitration by a single arbitrator** is sometimes provided for in the specifications. The single arbitrator may be chosen by agreement between the parties, but since these are already in a state of disagreement at the time when the arbitrator is to be chosen, it is better to have the arbitrator agreed upon at the time of the signing of the contract and named in the agreement.

23. As compared with the law courts, arbitration usually has the advantage of being immediately available, where it is not uncommon for the courts to be so overburdened with work that a case may be delayed for months or years. Where work is stopped as a result of the litigation, great hardship and financial loss may result from the delay. On the other hand, arbitration has the great disadvantage of not being binding upon the contending parties since a clause in the contract providing for arbitration cannot usually bar either party from going directly to the court. However, once an arbitration board has rendered a decision, neither party will have much chance to upset the decision in court unless they can prove fraud, collusion, or gross incompetency on the part of the arbitrators.

24. If a contract contains a clause intended to prevent either party from exercising his inherent right of appealing to the court, such a clause usually cannot be enforced. It follows that *arbitration is usually brought about only by the voluntary consent of the parties,* irrespective of whether specified in the contract or not. Some engineers have therefore contended that arbitration clauses might as well be omitted, since if the parties desire to arbitrate they can do so, and probably will

do so, even if there is no arbitration provided for in the contract. While this contention is sound logically and legally, it seems nevertheless wiser to provide the necessary machinery for arbitration in the shape of clauses agreed to by both sides, so that it can be set in motion at any time desired with a minimum of delay and confusion.

25. Bonds.—Through the engineer's decision, or, more commonly, through lawsuit or arbitration, the owner may succeed in establishing his *right* to certain damages, but when it comes to *actually collecting* the damages or other amounts awarded him the owner will often find himself in difficulties. The competent, honest, or wise contractor will rarely permit himself to be drawn into a controversy leading into the courts of law; it is more commonly the contractor lacking experience, funds, or honesty of purpose who gets into difficulties. The owner will usually find it impossible to collect from such a contractor because usually he has no visible assets. To protect the owner against such emergencies the contractor is required to furnish a **bond** or **surety,** whereby certain parties called the *bondsmen* pledge themselves to complete the work at their own expense in case of the default of the contractor, and, in general, to make good any financial obligations that the contractor may fail to satisfy.

26. The bond may be furnished either by private parties, usually two individuals called **bondsmen,** or by a *surety company*. A **surety company** is a company making a business of furnishing bonds for contractors and others, for which service it charges a fixed percentage of the contract price. Although a few owners still prefer the private bond, it is now a prevailing custom to accept only a bond furnished by a reliable surety company; because these bonds are easily obtained by a contractor having standing and assets, and they furnish adequate security. Besides, it may prove just as impossible to collect from private bondsmen as from the contractor. Where a bond has been furnished, it is very important that no major changes be made afterwards in the contract, since important deviations from original plans and

specifications may cancel the bond. The owner, therefore, before ordering any changes should always consult his attorney, and probably also the surety company, in regard to the influence of proposed changes on the bond.

27. Lien.—It might perhaps seem like an unfair and one-sided method to bond only the contractor but not the owner, since the owner may—and sometimes does—become entangled in financial difficulties that make it impossible for him to fulfil his obligations to the contractor. In point of fact, failure of the owner to discharge his duty is likely to endanger the contractor far more than the failure of the contractor to discharge his duties will endanger the owner. Aside from using ordinary business caution in dealing with the owner, contractors usually have only one legal protection, namely, that of the *lien* laws.

A **lien** is a legal claim against property as security for unpaid debts, the property usually being improved or in a state of construction. For example, under the lien law, a mechanic may retain a piece of machinery, upon which he has worked, until he has been paid for his time. Similarly, contractors, subcontractors, laborers, and material men may have a lien or claim against the structure upon which they have worked or for which they have furnished materials. The lien, when properly recorded, prevents the owner of the structure from disposing thereof, but it does not give an interest in the property to the one who files the lien. How to file a lien cannot be explained here, since the lien laws are state laws and vary from one state to another and the contractor usually gets his attorney's advice. In general, the lien must be recorded within a comparatively short time after the debt has been incurred in order to become effective.

An interesting question arises, when the owner neglects to pay his engineer or architect, as to whether or not the engineer or architect has a lien against the property. This question cannot be broadly answered by yes or no. In some states the engineer is protected under certain circumstances and in others not. Where occasion arises, such questions should be

submitted to a local lawyer skilled in construction and lien laws. It should be noted that liens are not effective against public property.

28. Local Labor and Building Laws.—Reference has already been made to the statutes of frauds and limitations, and to the laws concerning foreign corporations. Other local laws are the labor laws, which in some places determine wages and working hours for all or for certain classes of labor. In some places there are laws (usually building laws) requiring that the contract and sometimes also the plans and specifications be filed with the building department, the town clerk, or county clerk. All the larger cities have their own individual building regulations which are not entirely alike in any two cities, and in addition some states have state building regulations that sometimes elaborate and in other cases conflict with and often take precedence over the city regulations.

The local building and labor laws of any given locality will usually govern and control the practical execution of any construction work erected there, irrespective of where the contract is made. But all other questions involving the legality or enforcement of the contract itself will usually be decided according to the law of the place at which the contract was signed. For this reason, an engineering contract should indicate the place where it is concluded, although neither the *Uniform Contract* nor the *Standard Form of Agreement* of the American Institute of Architects contain any reference thereto. These documents will be considered in detail further on.

29. Local Customs.—Equivalent almost to the written laws of states and municipalities, are the **unwritten laws of custom** prevailing in many places and having reference especially to units of measure and methods of measuring. These peculiar customs are mostly found amongst the masons (both cut-stone and brick masons) and the plasterers, and take such forms as counting corners twice or disregarding openings partly or entirely. Special units are also sometimes employed; thus, masonry should always be measured by the cubic yard,

but in some places the *perch* is used instead. Although the dimensions of the **perch** legally are $16\frac{1}{2}$ ft.$\times 1\frac{1}{2}$ ft.$\times 1$ ft., equal to $24\frac{3}{4}$ cubic feet, the perch is, in some districts, assumed to be 22 cubic feet and in others 25 cubic feet.

AGREEMENTS

CONTENTS AND STANDARD FORMS

30. Contents of Agreement.—As already stated, the contents of the agreement are of a legal and financial nature, and usually comprise the following items: (1) Date of agreement and place where made; (2) identification of the contracting parties and their legal residence; (3) identification of structure and site; (4) identification of the engineer; (5) time of commencement and completion of the work; (6) total contract price; (7) method of payment; (8) damages for failure to complete the work on time; (9) enumeration of plans and specifications, and a clause expressly making these documents a part of the contract; and (10) the legal signatures of the contracting parties. Since each of these items can obviously be expressed in a short and clear sentence it is not necessary to consider them at length here.

31. General Form of Agreement.—The contents of the agreement should be presented in a short, concise, and logical manner, and in certain customary forms. There are different forms in use; most of these embrace the following three essential parts:

(1) A *preamble*, wherein the purpose and reason of the contract are set forth; (2) a *body,* in which is stated exactly and fully what each party to the contract undertakes to do and not to do; and (3) a *conclusion,* containing the signatures of the contracting parties.

32. Standard Forms of Agreements.—The agree ment is supposed to be prepared by the engineer, but since

very few engineers possess the training necessary for the development of original forms of legal documents recourse is usually had to so-called *standard forms,* of which several good ones are in existence. Federal and state authorities, as well as railroads and other large corporations, have their own standard forms which, for standard work, the contractor is required to sign. Large engineering and architectural firms also frequently have their printed standards. These have been developed by them through many years of experience, and have been prepared jointly by engineers, architects, and lawyers. In addition to these more or less private standards, there are in existence certain *standard forms* of documents intended for the general use of the public. Two of these that may be useful to the engineer although primarily intended for the use of architects are the following. The so-called *Uniform Contract,* prepared jointly by the American Institute of Architects and the National Association of Builders; and the *Standard Documents of the American Institute of Architects,* prepared by the Institute and approved by the National Association of Builders' Exchanges and other associations. The **Uniform Contract** is a complete agreement containing also some general clauses, and the **Standard Documents** comprise forms, not only of agreement, but also of general specifications, contractor's bond, agreement between contractor and subcontractor, and letter of acceptance of subcontractor's proposal. The two types of documents are not reproduced here because they are subject to change and revision. Copies can usually be obtained in local stationery stores, builders' exchanges, and architectural organizations, or direct from the Secretary of the American Institute of Architects, The Octagon, Washington, D. C., at nominal prices. Certain clauses may require change or elimination for a particular piece of work, and new clauses may have to be inserted.

SPECIFICATIONS

GENERAL SPECIFICATIONS

INTRODUCTORY

33. Division of Specifications.—As already explained, specifications may be considered as consisting of two parts: *general specifications* and *detail specifications.*

The **general specifications** contain all matters relating especially to business relations, and thus govern all trades on the job in distinction from the detail specifications, which must be prepared separately for each trade such as masonry, carpentry, concrete work, plastering, etc. The purpose of the general specifications is to define the general aims and purposes of the contract, and to serve as a guide in the daily relations between owner and contractor. The general specifications are sometimes called the *general clauses of the contract.*

34. Although the detail specifications will be considered in greater detail further on, it will be necessary to define them at this place, as they are so closely related to the general specifications that it is difficult to describe the function of one without referring to that of the other.

The **detail specifications,** together with the plans, are intended to define in detail the workmanship, as well as the quality and quantity of the materials to be used. Although in many cases a given statement may be incorporated in either the detail specifications or the plans, it may be said in general that the detail specifications define the workmanship and the quality of the material, by giving descriptions and that the plans define the quantities, by giving dimensions. Thus, the plans would indicate that a certain foundation block is

100 ft.×50 ft.×6 ft. in size, and the detail specifications would indicate that the mixture of the concrete for the block is to be 1:2:4, as well as the kinds of cement, sand, stone, and water to be used, and the method of mixing and placing.

35. Principal Features to Be Considered.—The general clauses of specifications will necessarily vary in scope and arrangement from contract to contract. Consequently, the specifications cannot be considered under one general head; yet their main features may be classified and explained in greater detail under the following divisions: (1) Definition of words; (2) documents of the contract; (3) financial matters; (4) relations between the contracting parties; and (5) installation and acceptance. These subjects will be briefly considered in the following pages.

DEFINITIONS OF WORDS

36. Language of Specifications.—The specifications should be so written that their meaning will be perfectly clear to the superintendent and foreman on the job. It is therefore essential that their language be simple, direct, and expressed in the proper and, so far as possible, common technical terms. Specifications so written should be largely self-explanatory, and should require few if any definitions of specific words. It is, however, advisable to preface the general clauses with a few paragraphs defining the words *owner, engineer, engineer's assistants, contractor,* and *subcontractor*. Since these terms have been defined before, no further reference will be made to them here. In addition, such terms as *written notice* and *work* are frequently defined.

37. Written Notice.—While the daily business between the engineer and contractor is transacted by ordinary correspondence, by word of mouth, or by telephone, a so-called **written notice** is usually required in cases where violation of the contract is alleged, and especially where the owner desires to discharge the contractor for failure to live up to the contract stipulations. The specifications should define just what

act constitutes the delivery of a written notice; such as delivery in person to the individual for whom it is intended if the delivery can be proved, or mailing by registered mail. Either of these methods is usually legal. In case the momentary whereabouts of the party may not be known, it may be stipulated in the contract that a registered letter addressed to the business address last known is a sufficient notice. As a matter of law, any letter sent by ordinary mail and addressed to the usual place of business of the addressee will usually be considered as a legally effective notice, provided the sender can prove that he has prepaid the postage and mailed the letter. This proof is most readily furnished by means of a post-office receipt such as given for all registered mail.

38. Work.—By the terms *work of contractor* and *work of subcontractor* is usually understood both labor and material, and the specifications should so state. Otherwise the contractor may claim that **work** is synonymous with *labor* only, in accordance with a quite common use of the term *work.*

39. Ambiguous Language.—The double meaning of the term *work,* explained in the preceding article, shows how difficult it is to avoid ambiguous language, and also how important it is that it should be avoided, since words or expressions having double meanings open the way for endless disputes. Therefore, great care should be taken to use language that can have but one meaning. But, because there is a possibility that some one may derive an unexpected meaning from even the most careful statement, a clause is often inserted in the specifications giving to the engineer the sole power of determining the true meaning of any ambiguous or conflicting language or statements in the contract documents. One common cause of conflicting statements arises from the repetition of statements intended to be the same. It often happens that in a subsequent revision, a change is made in one place but overlooked in another. The remedy is obviously to make each statement but once in the contract. A good rule to follow in writing specifications is to *avoid repetitions.* A better rule is to check thoroughly and carefully weigh each statement.

DOCUMENTS OF THE CONTRACTS

40. Enumeration of Documents.—It should be stated in the specifications that the contract comprises and includes the following documents: agreement, general specifications, detail specifications, and drawings.

41. Signatures.—For purposes of **identifications,** all the documents of the contract should be signed by both owner and contractor. Usually two copies of each document are signed, one copy being retained by the owner and one by the contractor.

42. Details of Shop Drawings.—While the agreement and specifications necessarily have been completed at the time the contract is signed, the plans are usually completed in part only, certain plans known as *details* and *shop drawings* being left for completion at a later date.

The **details** are plans usually made by the engineer (or approved by him) for the purpose of further elaboration of the general scheme shown in the contract documents; they must, of course, be consistent with the spirit of the original plans and specifications.

Shop drawings are plans made by a contractor or a subcontractor for the purposes of manufacturing or setting in place of certain parts of the work; such drawings are commonly prepared for cut-stone work, structural steel, reinforcing rods for concrete, and similar work.

It is usually a part of the engineer's duty to furnish the detail drawings in proper season, so as not to delay the contractor's work, but the engineer does not usually prepare the shop drawings. Generally, the shop drawings are made by the contractor or subcontractor, and copies are furnished to the engineer for his information by the contractor, and for the engineer's approval. Whatever method is adopted should be plainly stated in the specifications, and the number of copies to be furnished to the engineer should be indicated, as well as the purpose for which they are intended. One set is usually required to be returned to the contractor with the engineer's

approval indorsed thereon, or with the required changes indicated, if such are necessary.

43. Sets of Drawings Required.—There should be available for immediate reference, one complete set of drawings and specifications at the engineer's office and another at the job. Other sets are usually furnished by the engineer to the owner and to the contractor. Usually the engineer is required to furnish a certain number of sets of plans and specifications without cost to the contractor, and any additional copies at actual cost of reproduction. All the sets issued by the engineer are and remain his property, except the two sets signed by owner and contractor, and the specifications should so state. Upon completion of the work all plans, except those forming part of the contract, should be returned to the engineer.

Models are not commonly made on engineering work; if such are required they are, unless otherwise provided, made at the owner's expense and belong to him.

44. Conflicting Specifications and Drawings.—If there is no conflict between the various documents of the contract they are all equally binding and equally important. If, however, conflict is discovered, the several documents rank in the following order: agreement, general specifications, detail specifications, plans, details, and shop drawings. If conflict is discovered between figured dimensions on the same plan, overall dimensions govern detail dimensions; as between figured dimensions and scaled dimensions, the figured dimensions prevail. Large-scale drawings in general dominate small-scale drawings, except that the original drawings govern the detail drawings although the details are usually of larger scale. The sequence or relative importance here indicated is a matter of custom rather than of law, and the court will usually give equal weight to all documents so that, if an apparent conflict is discovered, the court will first of all endeavor to find a solution of the conflict that satisfies all the documents, even though this solution may not be the best from an engineering point of view. It is usual to state in the agree-

ment that anything called for in the specifications and not shown on the plans, or shown on the plans and not called for in the specifications, shall be as binding upon the contractor as if set forth in each.

FINANCIAL MATTERS

45. Classification.—The total stipulated consideration, or **contract price,** as well as the method of payment, is stated in the agreement, usually leaving for the general specifications only the details of the financial arrangement between owner and contractor. These details, which include also such subjects as extra work, sanitary policing, protection of adjacent property, insurance, workmen's compensation, etc., may be treated under the following headings: Additions and deductions; protections; monthly estimates; permits and licenses; royalties and patents.

46. Additions and Deductions.—Since practically no large contract job is ever completed without at least some changes from the original plans and specifications, it is always wise to stipulate in the specifications that the owner may order the necessary changes without invalidating the contract. The payments are increased or reduced in accordance with the change; and if there be a time limit for the completion of the work, a reasonable extension of time for doing such extra work must be granted the contractor. Reduction of the time on account of a moderate reduction in the quantities is usually not considered, nor required of the contractor.

Owing to the uncertainty of verbal understandings, all orders involving changes should be in writing, signed by the engineer or owner, as may be provided in the contract. The engineer can sign for the owner, legally, only after he has been duly authorized. It should be expressly stated in the specifications that "no claim for an addition to the contract price shall be valid unless ordered in writing." Notwithstanding any such clause, if the contractor puts in extra work without a written order, but with the knowledge and consent of the owner, and under the direction of the engineer, the contractor

will have a legal claim for a reasonable price for the extra work, even if a written order is absent. Usually the price for such additional work is agreed upon in advance in writing. Common methods of payment are: (1) By a **lump sum** intended to cover the entire extra work; (2) by a **unit price;** and (3) by the **cost to the contractor,** plus either a fixed sum or a percentage, to cover the contractor's overhead expenses and profit.

47. Protection.—All large contracts, and the majority of small jobs, endanger to some extent the property, welfare, and life not only of the owner and contractor, but also of neighbors, workmen employed on the job, and the public in general. These several interests are protected by a variety of sanitary, technical, and financial measures stipulated in the general clauses of the contract and briefly described in the following articles.

48. Sanitary Policing.—Sanitary policing of an intense kind is customary on all large public contracts in order to prevent spread of contagious disease by pollution of drinking water and streams. Even on small jobs it is customary to compel the contractor to maintain adequate latrines in good sanitary condition.

49. Protection of Adjacent Property.—Adjacent property is often endangered by the undermining of its cellar walls and other foundations by new building operations. Local laws are usually in existence, defining to what extent the builder must take care of adjacent foundations; but the specifications must be so worded as to make the contractor solely responsible for the proper protection of neighboring property and for any damages resulting from neglect of duty in this respect. Whether or not the owner can entirely escape his liability in case of damage to adjoining property, depends, however, upon local laws and upon the nature of the building contract. In some states the owner of a lot is responsible for the behavior of whatever he brings or causes to be brought thereon. If he brings upon the lot a wild animal that subsequently escapes and kills somebody, he is responsible,

and similarly if he builds upon his property a wall that subsequently topples over into his neighbor's house, he will be responsible for any damage to property, limb, or life caused thereby. In most states the contractor will, however, be responsible, unless he is legally acting as an agent for the owner. As previously explained, an agent is a person carrying out specifically defined acts on behalf of another person.

50. Calamities.—Calamities such as floods, cyclones, or conflagrations may arise; and in anticipation of such events the specifications usually permit and require the contractor to act at his discretion in order to prevent loss or injury, and to claim a reasonable compensation from the owner for any expense caused thereby. But notwithstanding any such clause, the contractor is usually required to protect his work against ordinary damage, and the owner's property against ordinary injury caused by the erection of the contract work. For such ordinary protection the contractor cannot claim reimbursement from the owner.

51. Liability Insurance.—In general, a man's **liability** is that for which he is responsible, but in construction work this word is more especially used to signify that particular responsibility arising from damages to property, limb, or life caused by the building operations, and resting usually upon the contractor. However, under certain circumstances of contract and law the owner may become primarily or jointly responsible. Such responsibility, arising through the acts of others or through contractual obligations, is called *contingent liability*. Insurance taken out to protect against liability is called *liability insurance*, or *employer's liability*.

52. It is always possible for the contractor to insure his men and the general public against accidental injury or death. It is a wise custom that compels the contractor, by stipulations in the specifications, to protect himself from claims for damages caused by accidents. Many insurance companies make a specialty of this form of insurance, or employer's liability insurance, charging therefor a fee based upon a percentage

of the contractor's payroll. In most states such insurance is regulated by law, and in many states it is compulsory under laws known as *Workmen's Compensation Acts,* and is often handled directly by a state department, to whom the contractor is required to pay the premiums, which may be a percentage of the payroll, or a lump sum.

53. Since the owner is likely to be made jointly responsible with the contractor for any damage to property, limb, or life caused by the building operations, he too is often required by the specifications to take out insurance protecting him against such claims. It might seem to be a matter of no importance to the contractor whether or not the owner was so insured, and therefore a matter not properly incorporated in the contract. However, when it is remembered that the damages frequently awarded by juries for personal injuries run into thousands of dollars, and for loss of life into tens of thousands, it will be seen that an accident may cause, as a final result, a liability of hundreds of thousands of dollars. Such a liability would bankrupt the majority of owners and contractors; and it is to protect themselves mutually against any such eventuality that liability and contingent-liability insurance are insisted upon by both parties to the contract.

54. Fire Insurance.—Many kinds of construction work are attended with considerable fire risk, most of all perhaps reinforced-concrete work carried on in the winter, with fires kept burning underneath the forms in order to accelerate the setting of the concrete. To protect owner and contractor against loss by fire, the specifications should call for *fire insurance* to be taken out for the joint benefit of owner, contractor, and subcontractor.

There are various ways of handling the insurance. Many engineering specifications call for the contractor to take out and pay for the insurance. In building work it is sometimes preferred to have the owner take out the policy, making him a trustee to *receive* any money due on account of fire insurance, and to *distribute* the money so received among those damaged by the fire, according to their loss.

Whether such items as insurance premiums and other similar incidental expense should be borne by owner or contractor is in the final analysis of no great importance, since if the contractor be called upon by stipulation in the contract to pay therefor, he merely adds the cost to his bid, so that in the end the owner pays the cost anyway. All such matters can therefore be arranged as seems most convenient in any particular case. The important thing is for the engineer to state definitely in his specifications just what method is to be adopted in each case, lest misunderstanding and dispute arise subsequently between the contracting parties, or perhaps a serious fire should occur and there be no insurance to cover the loss.

55. Bond.—Reference has already been made to the necessity of protecting the owner by a *surety bond* furnished by the contractor. There must be a clause in the general specifications calling upon the contractor to furnish such a bond; and this clause must state whether the contractor, as is usual, or the owner, is to pay the premium. As to the form of bond, the standard form of bond published by the American Institute of Architects may be used. An examination of a bond will show that it is apparently a contract without a consideration. As already explained, no contract is legally enforcible unless there is an adequate consideration, and it might therefore seem as if a bond was a contract made contrary to the usual rule. However, it is a legal principle that a *seal implies a consideration,* for which reason bonds are not only signed but also sealed, the seal making it unnecessary to state what the consideration is, or even that there is a consideration.

56. Permits and Licenses.—In most cities it is necessary to obtain a **permit** to build from the local building department. A fee is often charged for the permit, and the specifications must therefore state who is to obtain it and who is to pay the fee. Most cities have also regulations governing the occupancy of sidewalks or streets, the tapping of water mains and sewers, and so forth. The specifications must state in what manner such regulations affect the contract; and

who is to pay any fees arising therefrom. Although, in the end, all such expenditures are paid out of the owner's pocket, it is quite commonly stipulated in the specification that "the contractor shall obtain and pay for all permits and licenses."

57. Royalties and Patents.—It is customary to place upon the contractor the burden of paying all royalties due for the use of proprietary and patented articles or processes, of defending all lawsuits or claims for infringement brought by the proprietor or patentee, and of reimbursing the owner for any loss resulting from lawsuits over the unwarranted use of such articles, except in cases where such articles are expressly called for in the specifications. In some states it is illegal on public work to specify patented articles to the exclusion of other patented or unpatented articles answering practically the same purpose. These laws are frequently circumvented by adding the words "or equal" after the name of the patented article.

58. Monthly Payments.—On most jobs the contractor is paid monthly for the labor and materials furnished during the preceding month, less a certain percentage called the *retained percentage*. Sometimes he is paid in like manner at longer or shorter intervals. The **retained percentage** is an amount of money withheld from money due the contractor, for the purpose of creating a reserve fund wherewith to satisfy any unforeseen claims, especially claims of unpaid mechanics and material men, for which a lien can be filed. At the beginning of each month the engineer makes an approximate estimate of the proportionate value of the work done and materials furnished by the contractor up to and including the last day of the preceding month. From this estimate is deducted the sum of all previous payments and the retained percentage, and the remainder is the monthly payment that becomes due to the contractor. Where the method of monthly payment is adopted, the specifications should either stipulate the exact time of making payment or require the contractor to furnish to the engineer an **application for payment.** This application should be presented a few (often 10) days before payment is wanted, in order that the engineer may have an opportunity to check the

quantities claimed to have been placed. The engineer then issues a certificate, which indicates that the contractor is entitled to an amount obtained by means of the following formula:

$$M = A - \frac{Ap}{100} - B$$

where M = monthly payment;
A = total price of all the work done to date;
B = sum of all payments made to date;
p = retained percentage.

EXAMPLE.—On a contract involving a total of \$11,850, the contractor has received, so far, three payments; namely, \$1,550, \$1,200, and \$4,000. When the fourth payment comes due, the contractor submits an application for payment showing that the total value of work installed to date is \$9,500. (*a*) It being assumed that the engineer approves this figure, what would be the amount of the fourth monthly payment? The contract stipulates that 10 per cent. is to be retained. (*b*) After the monthly payment No. 4 has been paid, how much money remains on hand to complete the contract?

SOLUTION.—(*a*) The value of A=\$9,500; B=\$1,550+\$1,200+\$4,000 =\$6,750; and p=10.

By the preceding formula, $M = \$9{,}500 - \frac{\$9{,}500 \times 10}{100} - \$6{,}750 = \$9{,}500 - \$7{,}700 = \$1{,}800$. Ans.

(*b*) Total amount of contract=\$11,850. Sum of four monthly payments=\$6,750+\$1,800=\$8,550. Balance on hand=\$11,850−\$8,550 =\$3,300. Ans.

59. Payments Withheld.—The engineer is usually justified in withholding payments partly or entirely in the following cases: (1) Where defective work has not been remedied; (2) where it may reasonably be inferred that claims have been or will be filed; (3) where the contract cannot be completed for the unpaid balance of the contract price.

In order that there may be no doubt about the engineer's position in such matters, it is advisable and legally necessary to include in the specifications a clause setting forth in detail under what circumstances payment is to be withheld. In some states the laws protecting the claims of mechanics and material men are so strict that some engineers have found it advisable, when the bond is of doubtful value, to call for receipts showing

that all materials included by the contractor in his monthly application for payment have been paid for, as well as for an affidavit showing that all men on the contractor's payroll have been paid. Where such evidence is not forthcoming the engineer may be justified, if he can legally do so, in withholding payments, although by so doing he would impose a great hardship upon the contractor.

60. Materials Included in Monthly Payment.—In engineering contracts a difficulty sometimes arises in connection with the monthly payment because of those materials that are delivered at the site, but not yet incorporated in the work. The contractor, of course, is anxious to draw as much money as possible in order to facilitate his own financial operations, and so puts in a claim for materials delivered but not incorporated, while the owner is equally interested in not paying for goods that do not belong to him. In order to obviate this difficulty and so forestall any possible dispute, the specifications must contain a clause to the effect, for instance, that all materials paid for by the owner thereby become his property, and that the contractor must store and remain responsible for such material until it is placed in the work and accepted by the engineer. It is implied by such a clause that the contractor will be paid each month for materials delivered, even though they are not incorporated in the work, but it is of course better to state so explicitly.

61. Final Payment.—The last payment made is the one in which the retained percentage is paid or turned over to the contractor. Before the final payment is made the structure is given a **final inspection,** as a result of which, if everything is found to be as specified, the engineer signifies his **acceptance of the work.** If the engineer's decision is made final and binding by the specifications, the owner cannot claim further work or damages from the contractor after the final acceptance by the engineer. But if the engineer has no such powers, the owner can sue to recover damages from the contractor for any defects discovered within a reasonable time after completion. However, once the final payment has been

made the owner's prospects of getting any further services or attention from the contractor are very slight, and the final inspection should therefore be especially painstaking.

62. The final payment should not be made until a suitable time has elapsed after the completion of the work (as stated in the contract), in order that no outstanding debts of the contractors may cause a lien against the structure. A certain time limit, usually 30 or 60 days, is prescribed by the law of the state in which the lien must be filed; after the expiration of this limit the final payment can safely be made. If in special cases the contractor desires a prompt settlement, the engineer may sometimes be justified in granting a final payment before the expiration of the time limit upon receiving from the contractor and all subcontractors a so-called *discharge of lien,* which is usually a sworn statement to the effect that there are no recorded or unrecorded unpaid claims against either contractor or subcontractors. Quite often the specifications are so drawn that the final payment can be made only upon presentation of a discharge of lien.

RELATIONS OF THE CONTRACTING PARTIES

63. Limitations of Power of the Engineer.—Of prime importance are the clauses defining and limiting the powers of the engineer, since the entire interpretation of the contract and the relations between owner and contractor are influenced thereby as already indicated in several instances. Although the engineer prepares the specifications, it is poor policy for him to arrogate to himself unnecessary power, and to burden himself with the corresponding responsibility. In past times it used to be the custom for the engineer so to word the specifications as to make himself the sole judge of almost everything that went into the work, and to make his decisions final and binding upon all parties. Modern specifications usually provide that any decision of the engineer is rendered subject to arbitration, which clause in itself limits the powers of the engineer.

Another feature of modern specifications is to specify precisely and in detail what quality is wanted of materials and workmanship, leaving little room for any exercise of discretion in this respect, and thus considerably limiting the arbitrary powers of the engineer. This feature of the specifications is, however, more evidenced by the detail specifications than by the general specifications here under consideration. Suffice it to say, that where expertly drawn and judiciously worded requirements are included in the detail specifications, there will be but little room for deviation on the part of the contractor and therefore still less reason for arbitrary decisions on the part of the engineer.

64. Position of Superintendent.—In the erection of modern engineering structures, the work is often on too large a scale for individual efforts, and instead of an individual owner, contractor, or engineer, are found corporations, such as public service corporations, construction companies, and engineering firms. The specifications must state in such cases, as far as practically possible, what individuals are to represent the several concerns; and in order to insure especially that the contractor is adequately represented on the job, there must be a clause calling upon the contractor to have at all times a competent **superintendent** on the job, with whom the engineer can deal in all those innumerable minor questions that arise almost daily. Usually the specifications state that this superintendent or foreman must be satisfactory to the engineer, and that he cannot be transferred to another job so long as he is satisfactory to the engineer, unless he ceases to satisfy the contractor and is discharged for cause. Instructions given by the engineer to the superintendent are confirmed in writing to the contractor's office in all important cases.

65. Clauses Facilitating Supervision.—It is wise in many cases to have a clause requiring the contractor to furnish adequate facilities for inspection, such as safe scaffolds and ladders, to furnish the necessary labor to place and operate such facilities, and to remove any materials interfering with adequate inspection.

66. Owner's Right to Interfere.—It is customary and wise to have in the general specifications a clause permitting the owner to step in and complete all or part of the work in case the contractor neglects to prosecute the work properly, or fails to carry out any provisions of the contract. It is usually stipulated that 3 days' written notice must be given the contractor before the owner takes charge of any part of the work. The cost of work so done by the owner is to be charged against the contractor, but the contract is not necessarily terminated when a part of the work only is so affected, and the contractor will still be required to complete the other parts of his contract.

67. In aggravated cases the owner may desire to terminate the contract completely; and a clause should be inserted in the general specifications, giving him the right to do so in case the contractor should become insolvent; or if he should persistently neglect to supply a sufficiency of skilled workmen or adequate materials; or if he should fail to pay promptly and properly the subcontractors and material men to whom he is indebted on account of the contract; or if he should persistently disregard local or general laws and regulations or the instructions of the engineer. The clause covering these contingencies usually calls for a certificate from the engineer to the effect that sufficient cause exists for termination of the contract. This termination requires a reasonable notice (usually from 3 to 10 days); it gives the owner the right to take possession of the premises, together with the materials erected and stored thereon and the machinery, tools, and appliances there located, and to complete the work by whatever method he finds expedient. No further payments are made to the contractor, the owner using the unpaid balance of the contract price to complete the work; and if any money is then left over, it must be paid to the contractor upon the completion of the work. If the expense should exceed the unpaid balance, the contractor must pay the balance to the owner. Such action, however, cannot be taken without notice to the bond company and before an agreement is reached as to whether they, the owner, or another contractor shall complete the work.

Although clauses such as these are commonly incorporated in the specifications, it must not be understood that such clauses can be actually enforced without trouble. If occasion arises to use these clauses, a lawsuit is very likely to result. While these clauses are described here for the information and guidance of the engineer, it must be understood that legal matters and lawsuits are properly the field of the lawyer and not of the engineer.

68. Contractor's Right to Interfere.—The specifications must consider and give instructions for such eventualities as stoppage of the work through action of the courts and public officials. Usually the contractor is given the right to terminate the contract upon proper written notice to owner and engineer provided the stoppage exceeds a given length of time, such as 3 months. The contractor should also be given the right to terminate the contract and sue the owner for any amounts that, although certified for payment by the engineer or awarded by arbitration, remain unpaid for a specified number of days after they become due.

69. Relations Between Contractor and Subcontractor.—Since under the lien law the owner is responsible for the payments due to subcontractors, and since the owner pays the contractor and not the subcontractors, it is necessary to have a clause in the specifications stipulating as to when subcontracts will be allowed, and how and when the contractor is to pay the subcontractors. Usually each subcontractor is required to make his application for payment in ample time before the date for the estimates, or in time for the contractor to make his own application for payment; the subcontractor is then to be subsequently paid his proper share of the monthly estimate.

Clauses should also be found in the specifications to make the contract documents severally applicable to the work of the subcontractors; otherwise they might claim to be doing their work on the structure under a separate or different contract between themselves and the contractor. However, in such event the contractor would be responsible to the owner.

70. Disputes.—It is advisable to have a clause in the specifications setting forth what steps must be taken in case of dispute. A dispute will always take the form of either the owner or the contractor refusing to abide by some decision rendered by the engineer. Where arbitration is provided for, the dissenting party is usually required to file his demand for arbitration with the engineer, in writing. The specifications must then go on to state the number of arbitrators, how selected or appointed, authorization to make awards, how the award is to be formulated, and the arbitrator's compensation. Usually the specifications call for the arbitrators to name their own compensation. It is important also that the specifications call for the contractor to prosecute the work vigorously during the arbitration so that no delay shall meanwhile occur. Furthermore, it is always better for all parties to compromise a dispute than to try it out.

INSTALLATION AND ACCEPTANCE

71. Unpractical Stipulations.—It is frequent practice to state in the specifications that the work must be executed in "strict accordance with plans and specifications." If, however, it is the intention of the engineer to incorporate this clause in the specifications, he should be careful to place in the detail specifications only such requirements that he is prepared to force the contractor to live up to. A classical example of what is meant here is furnished by the time-honored clause that "all sand used in the concrete must be clean and sharp." There are many localities in this country where "sharp" sand is an unknown quantity and it is folly to call for materials that cannot be obtained or can be obtained only at prohibitive prices. The result is that such impractical clauses are generally ignored in practice.

In fact, structures are hardly ever built in strict accordance with the plans and specifications, but only in "substantial" accordance therewith. Thus, if the plans call for columns 18 inches square, how great a deviation from the 18 inches is permissible? Obviously, it is not physically possible to be

mathematically exact in such matters. Similarly, a floor is supposed to be level, and yet variations from a mathematical plane will always exist. Unfortunately, it is not customary, although it is desirable, to indicate in the specifications what deviations will be permissible; it is usually required merely that the work must be executed "to the satisfaction of the engineer."

72. Intention of Contract.—Even where the specifications make the engineer the sole judge, and his judgment final and binding, he is usually required by law to become "satisfied" when the intention of the specifications has been substantially complied with. In a lawsuit, the court will always endeavor to find what the spirit, or intention, of the contract is, taking all the contract documents as a whole, and if this spirit has been substantially complied with so that the structure conforms to the intended purpose, the contractor will be awarded payment for the work done, even though he may not have entirely fulfilled the contract in accordance with a strict interpretation. This is particularly the case with structures such as aqueducts, bridges, buildings, and railroads, because these are firmly attached to and become a part of the land, while in case of machinery or other movable appliances that can be turned back to the contractor and put to other use by him, the owner is justified in refusing acceptance on account of minor departures from the specified requirements.

73. Defective Work.—If, however, the work is actually so defective that the contract is not substantially fulfilled, one of the following two courses are open to the owner: (1) He may accept the defective work and pay under agreement with the contractor a reasonably lower price therefor. (2) He may insist upon the defective work being replaced by better and more adequate work. The specifications should be so drawn as to give the owner this option; however, where work is to be rejected and replaced, the engineer is bound to point out the specific defects that he desires to have remedied, so that the contractor may know just what is wanted. A mere statement that certain materials or work are unsatisfactory,

is not legally a sufficient notice of rejection; full and adequate reasons must be given.

74. Removal of Rubbish.—During erection the contractor should be required by the specifications to keep the premises in a neat and orderly condition, to remove accumulations of rubbish, and especially to remove at least temporarily any materials preventing work by other contractors or interfering with proper inspection. It should also be specified that, upon completion of the work, the contractor must remove all tools, equipment and surplus materials, clean up the surroundings of the structure and remove all rubbish. On large engineering work it is usually necessary to stipulate in considerable detail just what will be understood by the word *completion.* On a building, the contractor should be required to leave the job "broom clean"—that is, with all the dust, shavings, and earth swept out carefully, but not removed by washing.

Where several contractors work on the same job at the same time, each will usually try to pass the responsibility for the rubbish on to some one else, for which reason the owner should be given the right to remove all of the rubbish, and apportion the cost of removal to each contractor as the engineer may direct.

75. Final Inspection.—After the removal of all things to be removed, the contractor notifies the engineer to the effect that he is ready for the final inspection, and this is then proceeded with, all defects being carefully noted. Usually the **final inspection** should be carried out by another man than the one who was in charge of the inspection during erection, since otherwise mistakes left undiscovered originally may again escape detection. Just to what particular items the details of the final inspection are directed will depend largely upon the nature of the job; the inspection must include everything from a schedule of broken window panes to a verification of over-all dimensions. If no defects are discovered, a final estimate will ultimately be issued as already explained, but if any defects are found these must be remedied and the job again inspected before final acceptance.

76. Occupancy Before Completion.—In some cases the owner desires to occupy a portion of the structure before the entire structure is completed; this is especially true of buildings where the owner may occupy some of the lower stories during the completion of the upper stories. It may also happen that a portion of a highway or a railroad is taken into use before the entire road is ready; or in the construction of dams that the waters are purposely caused to rise behind the dam, by the closing of the gates, before the dam has reached its full height. Such occupancy by the owner does not necessarily imply an acceptance by him, unless expressly so stipulated, notwithstanding the fact that many contractors think otherwise. Thus, in the construction of a building, where the contractor had failed to comply with some material part of the contract, the owner moved into the uncompleted building and refused to pay the contractor the balance due him. The contractor brought suit to recover the balance due him and set up the claim that the owner's act of moving into the building was in fact an acceptance of the entire work. The court however decided against the contractor.

DETAIL SPECIFICATIONS

77. Classification of Contents.—In writing his detail specifications the engineer usually subdivides the subject matter according to trades, but this classification is not followed here because only the principles, and not the technical details, of the specifications are discussed. For the purpose of description, the following classification of the subject matter has been adopted: (1) *purpose,* (2) *materials,* and (3) *workmanship.* These obviously necessary divisions are followed by (4) a short separate description of specifications for *excavation,* since this subject presents some peculiarities of its own, and moreover is of such universal application that it deserves special explanation.

PURPOSE

78. Quality of Workmanship and Materials.—The purpose of the detail specifications is to give a complete description of the quality and kinds of labor and materials to be furnished by the contractor; the detail specifications are a necessary complement of the drawings, since on the drawings the sizes, quantities, and distances only are shown. Thus, the plans of a certain building will show the sizes and numbers of the window openings, while the specifications will indicate whether the glass is to be rough, ribbed, or polished; whether plain or wire glass is to be used, and whether single- or double-strength glass is required. In this manner the detail specifications become a collection of written instructions for the contractor's guidance.

79. Methods and Results.—The instructions given in the detail specifications should be directed to *results* rather than to *methods;* that is, the specifications should state what is wanted rather than how it is to be achieved. There is a very strong reason for this; namely, that the ultimate purpose of the contract is to procure for the owner exactly what he needs. How and by what means this result is brought about is usually of only secondary interest to the owner. The engineer, in preparing the plans and specifications, is the owner's agent, and the owner is therefore responsible for whatever results are brought about by the engineer's work. If therefore the engineer specifies methods of procedure the owner is generally responsible for the results produced by the methods specified. However, in some cases it is absolutely necessary to specify the method in order to get a desired result.

As an illustration, consider the construction of a large piece of masonry having its foundation under water. The engineer may be convinced that good results can be obtained only by building the foundations in the dry, and he would therefore write in his specifications that the foundation bed must be laid dry, and that the masonry must be built on the dry bed. With this specification before him the contractor must devise

his own methods of getting rid of the water, and since he has entirely free hands in selecting the methods he remains entirely responsible for the results.

But if, on the other hand, the engineer specifies that the contractor must put down a double row of 20-foot wooden sheet piling, filling the space between the two rows with clay puddle, to the entire satisfaction of the engineer and under his direction, and the contractor constructs the cofferdam in accordance with the engineer's direction then the owner becomes responsible; if the dam breaks, the owner must stand the loss. Under ordinary circumstances the engineer is not justified in placing this responsibility upon the owner. On the other hand, he would be justified in saying that the foundation should be obtained by the use of a cofferdam; or of a pneumatic caisson; or of an open dredged caisson. It is the engineer's duty to discover the precise needs of the owner, to describe a structure suitable for these needs, and to see that the contractor furnishes everything as described; in other words, the detail specifications should usually describe merely the results wanted. It is then the contractor's problem, except in special cases, to discover the ways and means of producing these results.

80. Specification of Methods.—Although, as stated, the methods of construction should generally be left to the contractor, exceptions may and often do occur. A case in point is in the construction of modern types of concrete and reinforced-concrete roads. Theoretically, it might suffice to specify that a certain type and thickness of concrete pavement is desired, to fulfil certain requirements in regards to strength and finish. In practice, however, it has been found far better to specify in great detail not only the proportions and kinds of materials to be used, but also how the materials must be mixed; how long they must be kept in the mixer; what type of mixer must be employed, and even in many cases the type of discharge apparatus. The methods of finishing the surface, and the appliances to be used for finishing, are also frequently described at length. Such elaboration is desirable where, as

in the case of concrete pavements, new and better methods are constantly being devised; but, as a result, the responsibility is very largely taken away from the contractor and placed upon the owner. If, therefore, the specifications insist upon certain kinds of materials to be treated, placed, and finished in a certain manner, and the result is not satisfactory, the owner often has no claim against the contractor provided the contractor can prove that he fulfilled the specifications "substantially."

81. Singleness of Purpose.—Since, as already explained, the respective responsibilities of owner and contractor are determined very largely by the spirit of the detail specifications, the engineer, in preparing his specifications, must choose whether to place the responsibility upon the one or upon the other. There is, however, nothing to prevent the owner from assuming responsibility for certain parts of the contract, leaving the responsibility for other parts to the contractor. If, in exceptional cases, it is found desirable to divide the responsibility between owner and contractor, the division line between the responsibility of one party and that of the other party must be clearly drawn. Where no clear distinction exists, trouble, confusion, and dispute are bound to occur.

Thus, as an illustration assume that there is a clause in the specifications to the effect that "the heating plant must be sufficient to heat all rooms to 70° F. in zero weather," while at the same time the plans show the sizes and locations of radiators, pipes, and boilers. Then, when zero weather comes on and the rooms can be heated to only 50° F., who is responsible? Naturally the owner will claim that the clause in the specifications governs, and that the contractor must put in a heating system capable of raising the temperature to the point specified, whereas the contractor will claim that as long as he has put in boilers, piping, and radiators as indicated on the plans, and has carried out the work in a substantial and workmanlike manner, the owner must be satisfied with whatever results are produced.

Parallel cases are frequently met with; they usually result in an expensive lawsuit, in which the decision frequently hinges upon the question whether or not the contractor has *warranted the plans;* that is, whether by act or implication the contractor has guaranteed the sufficiency and adequacy of the plans prepared by the engineer. This question is considered in the following article.

82. Warranty of Work.—It is a principle of law that whoever contracts to do a certain thing, thereby implies his ability to do this certain thing and to do it reasonably well. As far as the contractor's *warranty* of the finished structure is concerned, it is therefore always implied, whether so specified or not, that he must have reasonable ability to do the work well, and that he must exercise this ability reasonably well. Beyond this point the contractor is responsible only when he has undertaken to furnish an entire complete structure in good working order. A contract to furnish an entire complete structure is called an *entire contract,* as distinguished from the case where the contractor furnishes merely certain quantities of labor and materials toward the completion of the work.

Whether the contract is an entire contract or not, can be determined only by considering the contract as a whole, in order to discover the *intentions* of the contracting parties. If it be found that the intention was for the contractor to furnish an entire complete structure, it will usually follow that the contractor warranted the sufficiency or correctness of the plans, adopting them as his own, and becoming fully responsible therefor. If there are conflicting statements or errors in the plans and specifications it is then the contractor's duty to discover the conflict or error, to call it to the attention of the engineer, and to insist upon having it corrected.

83. If, on the other hand, the contract is not for an entire complete structure, the contractor cannot usually be held, in the absence of evidence to the contrary, to have implied a warranty of the sufficiency, correctness, or consistency of the plans and specifications. At the same time, the contractor may

warrant one portion of the structure and not other parts, or the contractor may imply a warranty against certain contingencies and not against others. Thus, if the contractor should suggest and cause to be accepted certain important modifications in plans or specifications, he would usually become responsible for the effect of the change, as might be the case where in the construction of a bridge a contractor who specializes in reinforced-concrete construction and holds himself out as an expert in this branch of engineering, causes a reinforced-concrete superstructure designed by himself to be substituted for one of structural steel designed by the engineer.

MATERIALS

84. Scope of Specifications.—It is necessary to indicate in the detail specifications what different materials are wanted and the kinds to be furnished of each. Thus, in connection with a large manufacturing plant, fastenings or anchors called *inserts* are usually required in the ceilings for the purpose of suspending shafting and motors. The inserts wanted may not all be of the same kind or size, and the specifications must clearly describe all the different kinds required.

Again, in the construction of a railroad, nut-locks or split washers are used to secure the bolts in the track from working loose; so the specifications must describe the kind or kinds required, since there are many different kinds on the market, and not all kinds may meet the particular requirements of the proposed railroad.

These two examples are purposely drawn from some relatively insignificant items of construction, in order to show that the detail specifications for any given structure must consider very many different and minute things in order to be even approximately complete. Some specifications contain a complete catalog of everything to be provided, with an adequate description of each item. To prepare such specifications is obviously a task calling for a wide experience and a complete technical knowledge, certainly not to be expected in a young engineer.

85. Nature of Requirements.—The requirements stated in the specifications are subject to three important limitations imposed by the very nature of the problems to be solved: (1) The requirements must be possible of fulfilment; (2) they must be in accordance with practice; and (3) adequate for the purpose.

Although in an architect's specifications the artistic or fanciful may sometimes be predominating, the engineer's specifications are almost always strictly utilitarian, dealing with a rather limited (although relatively large) number of items, such as steel, stone, cement, brick, asphalt, timber, and so forth.

Exhaustive series of tests of materials have been under way for many years, so that a fairly comprehensive knowledge has been gained of the best materials to use for many specific purposes; these tests have been carried on by governments, learned societies, universities, manufacturers' associations, and individuals. The test results have been compared with results obtained in the field, and out of the great mass of information thus gained there has sprung a practice which, while varying in many particulars, is nevertheless sufficiently uniform to warrant a certain amount of standardization. This standardization is expressed by the so-called *standard specifications* which are now available for many materials commonly used in engineering practice.

86. Standard Specifications for Materials.—Universally accepted in the United States are the standard specifications of The American Society for Testing Materials (1315 Spruce Street, Philadelphia, Pa.); these cover most of the materials used in building construction. Standard specifications for the materials and structures used in railroad construction have been prepared by the American Railway Engineering Association (431 South Dearborn Street, Chicago, Ill.). There are many other more or less widely accepted specifications for materials, but those here mentioned are the most important. Copies of them can be obtained from the societies named or can be found in the public libraries. The American Standards Association (29 West 39th Street, New York, N. Y.) is at

the head of national industrial standardization, and all information concerning standard specifications or standardization activities can be obtained from that Association.

87. Use of Standard Specifications.—The usefulness and importance of standard specifications can hardly be overestimated. Take as an illustration the standard specifications for Portland cement. Practically all the Portland cement manufactured in the United States is made to comply with the standard specifications of The American Society for Testing Materials, so that, instead of hundreds of different standards, practically all the cement now made conforms to this single definite specification.

When preparing specifications the engineer does not have to enumerate all the different qualities required of the cement or to describe how to proceed with the testing; he merely writes that all "Portland cement used on the job must comply with the Standard Specifications for Portland cement of The American Society for Testing Materials, and is to be tested in accordance therewith." If the cement is tested in accordance with such specifications and passes the test, the engineer knows positively that the material is of the best grade that can be obtained under ordinary commercial conditions and of standard quality.

88. Specifications for Other Materials.—There are many materials for which no standard specifications exist. When called upon to draw specifications for these the engineer must rely upon his own experience and whatever information he can obtain from textbooks and especially from other specifications covering similar ground. In regard to such materials a great deal of confusion exists, and this is especially true of such proprietary articles as paint, water-proofing compounds, and the like.

Excellent sources of information concerning all materials not standardized are the catalogs published by manufacturers, and no engineer should deem it below his dignity to seek information from such sources, or from the specialty salesmen who represent the manufacturers.

WORKMANSHIP

89. Lack of Suitable Standards.—No part of specification-writing taxes the ability of the engineer more than the writing of the clauses referring to workmanship. This is because it is difficult to find definite standards of comparison; in dealing with materials, it is possible to specify dimensions, unit strength, elasticity, color, hardness, specific gravity, and other physical properties, because these can be measured definitely by pounds, inches, or other established units; but to devise standards for workmanship is a hard task. In a great many instances this difficulty has been overcome by the simple expedient of writing that this or that item must be completed "to the satisfaction of the engineer," or else that "all workmanship must be of the best." Both of these expressions are very unsatisfactory because they are vague. When, it may be asked, is the engineer "satisfied," or what constitutes the "best workmanship"?

90. Prohibitory Clauses.—A step toward more definite requirements than the "satisfaction of the engineer" or the "best workmanship" referred to in the preceding article are clauses that in explicit terms prohibit certain common practices. A case in point is a clause prohibiting the use of retempered cement mortar in masonry. However, the better practice is to specify definitely what is wanted; this is not always possible, but should be done whenever it is feasible to do so.

91. Mandatory Clauses.—In some branches of engineering work it is possible to have a definite standard of workmanship. A clause, frequently incorporated in specifications for riveted steel bridges, may serve as an example. According to this clause, such accuracy of the location of punched rivet holes is required, that, when the several pieces are assembled, 40 per cent. of the holes can easily be entered by a rod having a diameter $\frac{1}{16}$ inch less than the holes; 80 per cent. of the holes can be entered by a rod having a diameter $\frac{1}{8}$ inch less than the holes; and all the holes can be

entered by a rod having a diameter $\frac{1}{4}$ inch less than the holes. This method gives a definite measure of the workmanship since it sets a definite numerical value for the degree of skill required in the workmen, and such clauses are always very desirable—provided, of course, that the requirements are practically possible of achievement.

A similar clause would require a rough concrete floor to be laid so nearly level that no part would project more than $\frac{1}{4}$ inch above the intended level and no part would be depressed more than $\frac{1}{4}$ inch below the intended level. Similar clauses in the specifications should cover the mixing, conveying, and placing of the concrete.

92. Limiting Clauses.—In writing specifications for many classes of work a peculiar difficulty arises from the circumstances that the progress of the work is contingent upon conditions entirely beyond the contractor's control. A case in point is in the construction of concrete work; concrete hardens much faster, and therefore becomes available for use much sooner, in warm weather than in cold. Consequently, it is impossible to specify how long the forms must be left in place; a time suitable for summer conditions would be entirely too short for winter work. In such cases, it is customary to specify that the forms must be left in place *at least* a certain minimum number of days, leaving the actual length of time to be decided by the severity of the weather and other conditions.

Similarly, the terms *not more than* and *not less than* are frequently used in specifications in order to limit the activities or choices of the contractor within certain definite bounds without tying his hands entirely. Where it is found altogether impossible to define the object to be gained, it has even been specified that the contractor must expend not less than a given amount of money for the particular purpose in view, under the direction and supervision of the engineer.

93. Although in some specifications separate clauses have been drawn up for materials and workmanship, the more common method is to treat materials and workmanship simul-

taneously, so that no sharp distinction is made between the two. This will in general be found by far the most convenient method of arrangement, owing to the great difficulty of treating workmanship as a separate entity apart from the materials to which it is applied.

EXCAVATION

94. Operations and Requirements.—In almost all engineering work it is necessary to do more or less excavating and back-filling, which work comprises also loosening, loading, hauling, dumping, leveling, and compacting of the material. Aside from the particular requirements of each individual job, there are two definite items common to practically all excavating jobs which must be treated in almost all specifications. These are: (*a*) *classification* and (*b*) *measurement.*

95. Classification.—Owing to the much greater expense of excavating solid rock than loose earth, it is necessary to distinguish between the two terms *rock* and *earth,* the former being commonly spoken of as hard and the latter as soft. Since in nature the one merges into the other through innumerable gradations of hardness and fragmentation, the engineer will often be called upon to classify a certain material about which doubt might exist. Hence, wherever possible the method of classification to be used on the job should be clearly indicated in the specifications.

The following are the two ways of distinguishing between rock and earth:

1. Everything that requires **blasting** with explosives is classified as **rock,** and everything else is classified as **earth.**
2. Everything that can be loosened by **plowing** is classified as **earth,** and everything else is classified as **rock.**

Where such definitions are used, boulders too large to be removed bodily and tree stumps are often classified as rock, and if such is the intention, the specifications should so state, indicating also the minimum size of boulder that will be considered as rock, as for instance, boulders containing $\frac{1}{2}$ cubic yard or more.

Many specifications give a more extended classification, covering loam, earth, sand, packed sand, gravel, clay, cemented gravel, hardpan, loose rock, and solid rock.

Then, other specifications give only part of the above, leaving the engineer to classify those not mentioned with the nearest in character to those that are mentioned.

96. The most satisfactory way is either to specify only earth and rock, or else to give a complete list, as above, from loam to solid rock. In the latter case no special experience is required to determine to which class any particular material belongs, and no more trouble arises than by using the criterion of plowing.

97. Measurement.—Owing to the fact that earth and rock expand when excavated, it is necessary to state where the materials will be measured, if they are to be measured by volume. Broken stone is sometimes measured by weight, but only when used as a commercial product, not when excavated in connection with engineering construction. There are three ways of measuring a volume of earth: (*a*) in its original site, (*b*) during transportation, and (*c*) after it has been deposited in its new site.

No two of these methods will give the same result. The earth swells when excavated, so that a larger volume must be transported than is indicated by measuring the solid earth in its original site. On the other hand the earth shrinks in volume when placed, so that, for example, the earth deposited in a railroad embankment occupies a smaller volume than it did in its original site.

Each of the three methods has its own particular principal use; thus, in grading for railroads and similar work the earth is usually measured in the original site. Dredged materials are sometimes measured on the scow while in transit and sometimes in the original bottom or site. Hydraulic fills are measured either in the original or in the final site. Nevertheless, there are many other cases where either method *could* be applied, and the specifications must always state which one is to be used.

STANDARD SPECIFICATIONS FOR SPECIAL STRUCTURES

98. Steel Structures.—In the engineering literature reference is often made to certain standard specifications prepared for special structures by engineers who have reached an eminent position within the profession. The specifications prepared for steel bridges by Osborn, Cooper, and Waddell are widely used and frequently quoted as examples; *Cooper's specifications* are especially well known, because they include a standardization of railroad locomotives according to weight and wheelbase, which has been widely followed by railroad companies and designing engineers in determining the loads for which proposed new bridges were to be designed. However, the General Specifications of the American Railway Engineering Association are now generally preferred in the case of bridges. The specifications in common use for steel mill buildings are those of Fowler and Ketchum. In the handbook of the American Institute of Steel Construction is included the standard specification for structural steel for buildings adopted by that Institute.

99. Concrete and Reinforced-Concrete Structures. A number of specifications for concrete and reinforced-concrete structures has been adopted and published by the American Concrete Institute, including specifications for one- and two-course concrete pavements, sidewalks, curbs and gutters, plain and reinforced-concrete floors, and concrete sewers. These specifications have been printed in the Proceedings of the American Concrete Institute, copies of which may be consulted at many public libraries throughout the United States.